Pedometer-Determined Physical Activity Levels and Adiposity Amongst Year 7 Students in Tower Hamlets

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2013

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This thesis is submitted as part of the requirements for the degree of Doctor of Philosophy.

ABSTRACT

Background: Tower Hamlets is a socioeconomically disadvantaged borough, home to the UK's largest South Asian population, a group at increased risk of obesity-related diseases. Previous studies in this population have reported high levels of adiposity and inactivity. No borough-wide study has been conducted objectively measuring physical activity patterns. This study aimed to investigate pedometer-determined activity levels of Tower Hamlets' schoolchildren, their association with adiposity and differences according to ethnicity and socioeconomic status (SES). The study was preceded by reviews investigating the association between step counts and adiposity in children and investigating the validity of pedometers as a measure of physical activity in young people.

Methods: Participants were recruited from Tower Hamlets' secondary schools (n=884; 584 boys, 300 girls). A pedometer was worn for 7 days. Internationally recognised mean daily step count cut-offs (boys = 15000, girls = 12000) were used to define activity level. Body mass index (BMI), bioelectrical impedance analysis (BIA)-determined percentage body fat (%bf) and waist circumference (WC) were all measured. Children were classified as being of normal weight, overweight or obese according to international cut-off points. A questionnaire was administered to establish socioeconomic status and ethnicity.

Results: A total of 884 schoolchildren were recruited (66% boys, 34% girls). Of this, 657 (74%) provided a full set of pedometer, anthropometric and socio-demographic data. Sixty-five percent of all participants were South Asian and 55% received free school meals. Significant differences in anthropometric variables were observed according to gender, ethnicity and school. The prevalence of overweight/obesity ranged widely for boys (35%, 53% and 65%) and girls (33%, 55% and 55%) according to BMI, %bf and WC, respectively.

The majority of participants provided 4 or 5 days of activity data, with 15% providing data for 7 days. Inactivity was high, 83% of boys and 72% of girls failed to meet the minimum recommended daily step counts. Activity was greater during the week compared to the weekend and those that were most active during the week were also more active at the weekend. Boys (11580±3560) took significantly more steps than girls (10062±3239) and differences were also observed between schools. No significant differences in activity levels were observed according to ethnicity, SES or adiposity levels.

Conclusion: The vast majority of schoolchildren in Tower Hamlets fail to reach current physical activity recommendations, irrespective of ethnicity or socioeconomic class. Inactivity is greater at the weekend. The prevalence of overweight/obesity is also higher than national averages. Intervention strategies to increase physical activity and tackle overweight/obesity in this cohort are required.

ACKNOWLEDGEMENTS

I would like to sincerely thank my supervisors, Dr. Zoe Hudson and Prof. Stephanie Taylor. I have learnt so much from them throughout the course of this PhD. They provided me with a wealth of advice and guidance, which was consistently helpful and motivational. Most of all, they were always kind, positive and encouraging, even when such generosity may not necessarily have been deserved. I'm very appreciative of that and I can only hope that this thesis does justice to the amount of effort that they have invested in me.

I would also like to thank all of the staff at the Centre for Sports and Exercise Medicine. Not only did they provide a friendly and inspiring atmosphere for me to work in, there was always someone present who was willing to provide advice, support and help whenever I needed it.

I am also very thankful to the schools, their staff and students that participated in the study. They were very accommodating and always enthusiastic to be involved with the study, providing the data I needed. Attending the schools also acted as a welcome break from sitting at my desk.

Thanks also to my friends, for providing much needed distractions to take me away from my studies.

I owe massive thanks to my family; my sister Aoife and my parents, Anne and Kevin. They could not have been more encouraging and supportive throughout, offering me any help that they could. I take great comfort in knowing that although they may be on the far side of the Irish Sea, they are always there for me. I really appreciate that.

Finally, I would like to give thanks to my girlfriend, Frances. She has been a wonderful source of support throughout the course of the PhD, always encouraging, kind and patient. Simply knowing that she was there, at the end of every difficult day, helped me immeasurably in completing this thesis and staying happy throughout.

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GLOSSARY

BIA	Bioelectrical Impedance Analysis
BMD	Bone Mineral Density
BMI	Body Mass Index
BMR	Basal Metabolic Rate
CDC	Centre for Disease Control and Prevention
CMO	Chief Medical Officer
CVD	Cardiovascular Disease
DIT	Diet Induced Thermogenesis
DoH	Department of Health
EE	Energy Expenditure
IOTF	International Obesity Task Force
MET	Metabolic Equivalent
MVPA	Moderate-to-Vigorous Physical Activity
NHS	National Health Service
ONS	Office of National Statistics
SES	Socioeconomic Status
TEF	Thermic Effect of Food
THC	Tower Hamlets Council
WC	Waist Circumference
WHO	World Health Organisation
%BF	Percentage Body Fat

CHAPTER 1 – INTRODUCTION

This thesis describes a large-scale cross-sectional study investigating the physical activity levels of a multi-ethnic and socio-economically deprived sample of children from East London. The thesis provides background to importance of physical activity research, highlighting the need for such research in East London, thus developing a unique research question. Detailed methodology and results are then presented and the findings are discussed with respect to the study's unique population and wider social perspective.

Chapter two begins by defining physical activity, detailing both its components and dimensions. This chapter also investigates the important health benefits associated with being physically active. These include both physical and psychological health benefits. Particular attention is paid to the nature of the role that physical activity plays in helping to maintain a healthy weight. The benefits of developing a physically active lifestyle from a young age are also highlighted, tracking as it does from childhood through to adulthood. Having established the importance of physical activity, the history of specific activity recommendations for young people is critically evaluated, including government-developed time-based recommendations and internationally-recognised step count recommendations.

The third chapter further explores physical activity, first discussing the importance of measuring the physical activity levels of young people. It covers important considerations regarding the design and methodology related to studies investigating young people's physical activity. What dimension of activity should be measured? If intensity of activity is to be recorded, is time active or steps taken a more informative measure? Should the metabolic (energy expenditure) or mechanical (movement) component of activity be measured? Consideration is also given to the unique nature of children's physical activity as well as study size and budget. This section concludes that the key to the successful measurement of physical activity in young people is to balance a measurement tool that is validated, reliable and accurate with a practically feasible option relevant to the aims of the study and the cohort involved. This conclusion is considered in the context of a recent trend in activity research to reject individual-based, detailed activity studies in favour of large-scale studies investigating activity behaviour at a population level.

In chapter three, a variety of physical activity measurement methods, both direct and indirect, are reviewed. While low cost questionnaires are a valid option, the less costly of the direct methods, employing accelerometers and pedometers, are deemed more favourable for use in large-scale studies involving children. The latter method, which records step counts, is evaluated in more detail in a comprehensive literature review, confirming pedometers as a valid method of activity measurement, particularly in activity studies involving children.

The issue of adiposity in young people is addressed in the chapter four, again focussing on the most valid measurement methods in epidemiological studies involving children. A subsequent literature review describes the association between activity and adiposity in young people. In particular, the nature of the association between step counts and adiposity is investigated, based on the hypothesis that pedometers are a valid method of activity measurement. The review highlights a lack of consistency regarding this association, citing the important role played by confounding factors, including age, sex, ethnicity, location and socioeconomic status.

Tower Hamlets, the local borough in which the research was proposed to take place, is profiled in detail in chapter five, with particular attention being paid to the ethnic and socioeconomic profile of the borough's child population. Tower Hamlets has the largest Bangladeshi population in England and over 50% of the total borough population are from non-white British ethnic groups. It also has the highest prevalence of child poverty in the country. Previous research regarding the health of children in the borough is discussed, highlighting poor trends with respect to both activity and adiposity. However, it is noted that to date, there have not been any large-scale studies providing objectively measured physical activity data for young people in

Tower Hamlets. Also, there have not been any studies investigating the association between objectively-determined activity and adiposity in this particular population.

The primary research questions, aims and objectives are then listed. The main research questions for this study are:

1. Do ethnic differences exist in the pedometer-determined physical activity levels of Year 7 students in Tower Hamlets?
2. Are socioeconomic status or ethnicity determinants of health status, as determined by activity and adiposity levels, in this population?
3. Is there an association between pedometer-determined physical activity and adiposity and is this association influenced by ethnic or socioeconomic differences?

These research questions will be addressed through the following aims:

i. What are the mean daily, weekday daily and weekend daily step count levels of this population?
ii. Do ethnic or socioeconomic differences exist in the step count levels of this population?
iii. Do gender, age or school differences exist in the step count levels of this population?
iv. What are the adiposity levels of this population, as measured by body mass index (BMI), waist circumference (WC) and bioelectrical impedance analysis (BIA)-determined percentage body fat (%BF)?
v. Does a significant association exist between pedometer-determined activity and adiposity and what are the significant correlates of this association?
vi. What are the step count recommendation-derived activity levels of this population and are the recommendations suitable for all ethnic groups?

The specific objectives of the study are:

- Collecting data regarding age, sex, ethnicity and socioeconomic status using a questionnaire

- Collecting seven days' pedometer data from all students involved in the study
- Measuring BMI, WC and BIA-determined %BF for all students
- Using recognised cut-offs to investigate both activity levels and levels of overweight and obesity
- Analysing and reporting significant differences in physical activity and adiposity data according to the socio-demographic variables
- Analysing and reporting significant correlations between activity and adiposity, controlling for significant socio-demographic covariables

The results of the study are presented in chapters seven and eight, the first primarily concerning adiposity and the second primarily concerning physical activity. Chapter seven first describes recruitment rates and the demographic profile of participants. Significant differences in adiposity levels are presented according to age, sex, ethnicity, socioeconomic status and school using bivariate analysis. Where suitable, multivariate analysis is conducted. A similar analysis plan is applied to the physical activity data in chapter eight. Finally, the association between activity and adiposity is presented. Confounding variables for this relationship are also considered through multivariate analysis.

These results of the study are critically evaluated in detail in chapter nine. Attention is also paid to other potential correlates of physical activity. Cultural and environmental differences, along with health inequalities associated with socioeconomic deprivation and limitations of the study are considered. The study concludes with a summary of the findings, a consideration of their unique nature in terms of adding to this field of research and also considerations for future research.

CHAPTER 2 – PHYSICAL ACTIVITY IN YOUTH

2.1 What is Physical Activity?

The term 'physical activity' is often loosely applied to a wide variety of behaviours and phenomena. However, it is classically defined as any bodily movement produced by skeletal muscles that leads to an increase in normal energy expenditure (Caspersen et al., 1985). It can be broken down into four general components; occupational activities, household activities, transport and leisure activities (Caspersen, 1989).

2.1.1 Components of Physical Activity

Of the four main components of physical activity (Bouchard and Shephard, 1994), the first two, occupational and household activity, are somewhat self-explanatory. Occupational and household activities cover all general movement that takes place either in the workplace or at home. These activities can range widely depending on an individual's specific job, daily routine, behaviour and lifestyle, from stapling paper or tying your shoe laces to sweeping floors or moving a piano. Every single bodily movement in either of these environments, in the workplace or at home, is classed as some form of physical activity. For children and teenagers, occupational activity can be substituted with all school-based activity. This includes all movement necessary to complete a normal structured day at school, aside from leisure-time activity and transport.

Transport is the third component of physical activity and it is defined as a person's movement from one location to another. It is important to bear in mind the distance travelled and the means employed to do so when discussing transport. This covers all steps taken during the day, be that an hour-long walk to and from your place of work or just walking up a short set of stairs. In terms of the means employed, aside from walking transport also refers to other methods of travel such as cycling and running. When referring to children, their primary transport activity is the daily commute to and from school, be it walking or cycling.

Leisure-based activity refers to a wide range of activities. This includes all other activity that a person partakes of outside of the necessities of daily life, working, travelling and completing general daily chores. Leisure-based activity includes all sports (organised and un-organised), exercise, hobbies and other interests too. Leisure also includes physical education classes and all school and extra-curricular sports.

2.1.2 Dimensions of Physical Activity

Physical activity can be described in terms of frequency, duration, intensity and type (LaPorte et al., 1985). Frequency simply describes how often the physical activity occurs. It is usually expressed as number of times per day, week or year. Similarly, the duration refers to the length, measured in time, of the physical activity, e.g. to walk for 30minutes. Type is important as it describes the activity. For example, swimming and jogging might be comparable in terms of intensity, but swimming will use more muscle groups while walking is a weight-bearing activity.

Physical activity intensity refers to how difficult it is. It can be expressed as either a continuous or discrete variable. As a continuous variable, the metric employed to describe intensity will be dependent on the method of measurement. For example, pedometers provide information on physical activity intensity in the form of steps per unit time, while a heart rate monitor provides information on intensity in the form of time spent above a specific heart rate. Activity intensity can also be expressed in terms of accelerometer-recorded movements or metabolic equivalents (METS).

The metabolic equivalent or MET is a concept that describes the energy expenditure associated with physical activity (Ainsworth et al., 1993). One MET is equal to a metabolic rate of 1 kilocalorie per kilogramme or body weight per hour. This equates to 3.5 millilitres of oxygen per kilogramme of body weight per minute (Byrne et al., 2005). All forms of physical activity can then be coded to represent multiples of one MET.

As a discrete variable, usually measured through subjective methods, activity intensity can be reported as normal, moderate or vigorous. It can be classified in a number of ways depending on the method of measurement. Using previously established step count cut-off points (15,000 steps/day for a boys, 12,000 steps/day for a girl) (Tudor-Locke et al., 2004), a person can be described as being either active or inactive. Activity intensity can be classified as sedentary (inactive), light, moderate or vigorous. While sedentary behaviour implies a minimum amount of movement, moderate intensity activity is comparable with general household/occupational tasks and chores, or a brisk walk. Vigorous intensity activity leads to an increased heart rate and rapid breathing, and includes activities like running, swimming and heavy labour.

When describing physical activity intensity in terms of METS, specific guidelines have been developed, covering a wide range of activities. A sample of the activities is presented in table 2.1.

Table 2.1 - A Sample of Activities Classified According to MET-determined Intensity

Intensity	Task	METS
LIGHT:		< 3
	Sleeping	0.9
	Cleaning, sweeping with light effort	2.3
	Sitting, playing with children, light effort	2.5
MODERATE:		3 – 6
	Walking at 3mph	3.3
	Cycling, leisurely at >10mph	4.0
	Home repair, painting	5.0
VIGOROUS:		> 6
	Sawing hardwood	7.5
	Swimming, front-crawl fast	11.0
	Cycling, uphill vigorously	14.0

(Ainsworth et al., 1993, 2011)

Physical activity that is less than 3 METS is deemed to be of light intensity, comprising of activities from sleeping to slow walking. Moderate intensity activity, such as light cycling and housework, is anything between 3 and 6 METS. Any activity greater than 6 METS, things like housework and exercise that require significant effort, are deemed to be of vigorous intensity (Ainsworth et al., 1993, 2011).

2.1.3 Physical Activity, Energy Expenditure & Exercise

Despite the fact that activity can be defined in the context of energy expenditure, physical activity should not be confused with either energy expenditure or exercise.

The latter is one component of physical activity, while the former is the sum of all physical activity, the thermic effect of food and the basal metabolic rate.

Every day, regardless of one's lifestyle, most people use a baseline minimum amount of energy to maintain basic bodily functions. This is known as the basal metabolic rate (BMR) and it accounts for the energy that is expended while maintaining normal cardiovascular, respiratory and thermoregulatory function (Mitchell, 1962). On average, BMR amounts to approximately 60-75% of a person's total energy expenditure. This is coupled with diet induced thermogenesis (DIT), also known as the thermic effect of food (TEF). This is the energy required to digest, absorb, and transport nutrients. DIT accounts for around 10% of all energy expenditure. All other energy expenditure is referred to as physical activity, accounting for 15-30% of one's total energy expenditure (McArdle et al., 1994), depending on how active they are.

As mentioned above, exercise is only one element of the leisure-time component of physical activity. It is defined as physical activity that is planned, structured, repetitive and purposeful, the aim being to maintain or improve physical fitness (Caspersen et al., 1985). Again, the amount of energy expended on exercise varies widely depending on a person's lifestyle. Older, disabled or inactive people may do no exercise at all while a full-time professional endurance athlete (cycling, marathon) will spend a number of hours exercising daily.

2.2 Health Benefits of Physical Activity

The importance of a physically active lifestyle stems from the fact that low activity levels and sedentary behaviour are associated with many health issues. There is a large body of evidence linking physical activity to a wide variety of potential health benefits; examples include weight management, prevention of cardiovascular and other metabolic diseases and reduced risk of premature mortality. It aids growth and development in young people and combats the onset of premature morbidity and mortality in adults. At the same time, international trends suggest that physical activity levels amongst young people are low and they do not seem to be improving. This is occurring in tandem with rising levels of obesity in both young people and adults, caused by an inequality between energy expenditure and energy intake including physical activity (Spiegelman and Flier, 2001).

Physical activity, especially in the form of exercise, can provide a multitude of different benefits from childhood, through adolescence and into adulthood and old age (1996). These potential benefits are both physical and psychological in nature. Children, can achieve musculoskeletal, cardiovascular and neuromuscular gains through physical activity. For older people, activity provides an important opportunity to maintain functional mobility and reduce the risk of cardiovascular and other chronic diseases. Throughout the life-course, exercise may also provide the opportunity for children to socialise, develop self-efficacy, while also relieving stress, anxiety and depression.

2.2.1. Physical Health Benefits

The health benefits most commonly associated with physical activity are the prevention and treatment of chronic diseases. These include cardiovascular disease (Andersen et al., 2006), type II diabetes (Manson et al., 1992) and cancer (Friedenreich and Orenstein, 2002), amongst other less prevalent conditions. Such diseases usually require extended periods of incubation prior to onset. Associated risk factors may be detected in adolescence or, more probably, in early adulthood. However, the diseases themselves do not tend to present themselves until early to mid-adulthood (figure 2.1), early onset type II diabetes excepted.

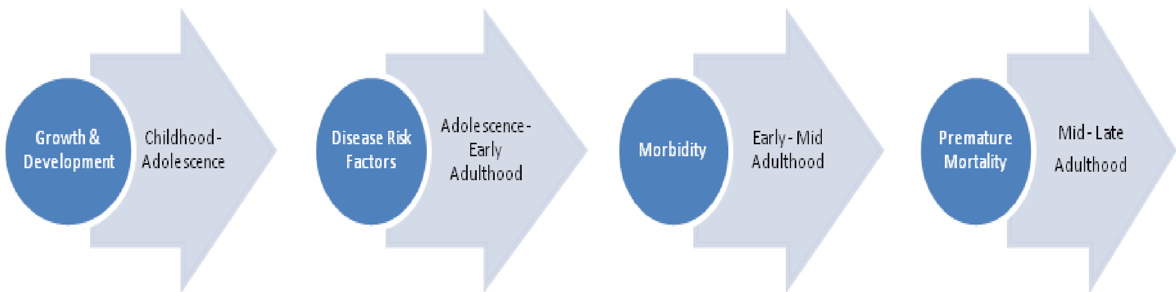


Figure 2.1 – Health Risks Associated with Inactivity from Childhood to Late Adulthood (Hallal et al., 2006)

Whilst an early risk factor for cardiovascular disease, such as obesity, may develop and present itself in adolescence, the disease itself and the risk of premature mortality associated with it will not be experienced until adulthood (Hallal et al., 2006). Fittingly, chronic diseases are much less prevalent in childhood compared with adulthood. Resultant morbidity and premature mortality do not tend to present themselves until mid to late adulthood. However during childhood and into adolescence, there are other possible areas through which physical activity can be beneficial, promoting healthy physical growth and development.

2.2.1.1 Maintenance of a Healthy Weight

The full nature of the relationship between physical activity and obesity in youth has not been established, although there is much evidence to suggest that an inactive lifestyle may result in children and adolescents suffering with weight control issues (Ekelund et al., 2002, Schmitz et al., 2005). The lack of clarity regarding the relationship can be partly explained by the wide variety of methods employed to determine activity and obesity. The issue is also clouded by the fact that obesity is affected by a wide variety of determinants, with physical activity just one of them. With this in mind, the exact nature of the relationship between objectively measured physical activity and obesity is reviewed in much greater detail in section 4.3.

While the full extent of the association between physical activity and obesity in youth remains quite ambiguous, there is a widely held opinion that a healthy, physically active lifestyle in youth can have a positive effect on weight control, reducing if not preventing overweight and obesity. This may be beneficial in the long-term for two main reasons. Firstly, as mentioned in the section above, obesity is the only lifestyle-related, chronic disease risk factor to develop in youth. Treating or combating obesity in youth may delay, if not totally prevent the onset of morbidity in adulthood. The main health benefit of physical activity may actually be an indirect one; by combating obesity, physical activity can indirectly reduce the risk of cardiovascular disease and other chronic conditions.

Secondly, there is evidence to suggest that obesity can be tracked through life (Mossberg, 1989, Whitaker et al., 1997). That is to say that the development of overweight or obesity at a young age will determine, to some extent, the risk of such conditions in adulthood. As a result, the longer that obesity is left unaddressed early in life, the more pressing an issue it will become in later life. A recent systematic review carried out by Singh and associates (2008) concluded that of the 25 studies included (predominantly published since 2001), all reported and increased risk of becoming an overweight or obese adult if you were an overweight or obese child.

In a longitudinal study carried out by Whitaker and associates (1997), 854 participants provided body mass index (BMI) data at regular intervals between the ages of 0 and 21. Parental BMI data was also gathered for comparative purposes. Participants (children and parents) were classified as normal weight or obese and the likelihood of obesity in adulthood based on childhood obesity status and parental obesity status was calculated. Of all those participants that were obese 10-14yr olds with at least one obese parent, 79% were reported as being obese adults too. The likelihood of obesity in adulthood increased considerably as the age of the obese child increased. Adjusting for parental obesity, the odds ratio of adult obesity ranged from 1.3 for obese 1-2yr olds, to 17.5 for obese 15-17yr olds. This trend seemed consistent regardless of parental weight status, emphasising the importance of tackling obesity as early as possible.

Another longitudinal study, carried out by Starc and Strel (2011) over the course of twelve years, gathered BMI data from 4833 subjects at ages 7, 11, 14 and 18. The study reported that 40% and 48% of men and women, respectively that were obese at aged 18 had been obese for the previous 7 years. The authors again highlighted the need to combat overweight and obesity at a young age. Another similarly designed study, spanning 22 years, also reported alarming trends (Herman et al., 2009). BMI measurements were taken from 374 7-18yr olds on two occasions, 22 years apart. The study reported that 83% of overweight children were also reported as being overweight or obese in adulthood. In fact, overweight children were over six times as likely to be overweight adults as their normal weight counterparts.

An overwhelming majority of evidence consistently suggests that the treatment and prevention of adiposity in youth is essential to realise both short and long-term positive effects, reducing the risk of obesity-related chronic diseases from childhood through to adulthood. The full extent of the role played by physical activity is not yet understood. The association between activity and adiposity is affected by a wide variety of confounding variables, amongst them gender, age and ethnicity. However, activity is established as a key determinant of obesity. As a result, the promotion of physical activity may be of benefit in reducing the risk of obesity and related diseases. Further research is warranted to investigate the association between physical activity and adiposity. Particularly, research is warranted that investigates the association between activity and adiposity while also investigating the role of key confounding variables. In this regard, comparisons according to gender, age and ethnicity may help to provide a clearer insight into this contentious issue.

2.2.1.2 Musculoskeletal Health Benefits

Physical activity benefits young people by aiding healthy growth and development. Specific gains associated with physical activity, and particularly exercise, include muscular strength and endurance, as well as skeletal health.

Young people rapidly gain bone mineral density during adolescence, peaking at 12 for girls and 14 for boys (Theintz et al., 1992). This is a very important stage in development as it will, in the long-term, affect bone mass loss and the risk of developing osteoporosis in later life. The tensile and compressive forces associated with weight-bearing activities are beneficial to the growth of skeletal tissue. This is supported by the findings of both retrospective studies of physical activity in childhood in relation to bone mass in adulthood (Kemper et al., 2000, Valimaki et al., 1994) and comparisons of active and inactive children and adolescents (Afghani et al., 2003, Nordstrom et al., 1995).

In the study by Kemper and associates as part of the Amsterdam Growth and Health Longitudinal Study (2000), 182 participants had physical activity measurements taken from ages 13 to 29. When all the activity data was collected, bone mineral density

(BMD) was measured at three sites for all subjects. Physical activity in adolescence and in young adulthood was found to be significantly and positively related with both hip and lumbar BMD.

Slemenda and associates (1991) recorded the activity levels and bone mass of 118 children, aged 5-14 years. A positive relationship was observed between BMD at the radius, spine, and hip and most activities. Weight-bearing activity, in particular, was significantly related to BMD at both the radius and hip. The findings suggest that important developments in skeletal mass and BMD are achieved through physical activity in youth.

Bearing this and similar evidence in mind, government physical activity guidelines for children include specific recommendations to perform high impact activities that place stress on bones (CMO, 2004).

While cross-sectional studies provide slightly ambiguous results, longitudinal studies indicate that there is a positive benefit to physical activity on upper body muscular endurance (Beunen et al., 1992). Physical activity has also been linked with neuromuscular benefits, specifically neuromuscular coordination. Not much research is available regarding the association between physical activity and neuromuscular coordination in children. However it is accepted that neuromuscular coordination is developed through the repetition of specific actions that require coordination (Kottke, 1980). The ability to juggle requires practice. Similarly, it seems intuitive that a child will improve its ability to kick, throw and catch a ball primarily by doing so regularly. This can only be done by being physically active and taking part in sport and exercise.

2.2.1.3 Cardiovascular Disease

Cardiovascular disease (CVD) is a term given to a group of disorders of the heart and blood vessels (WHO, 2011a). It includes coronary heart disease (CHD), stroke and hypertension. CVD accounts for approximately one third of all deaths worldwide, usually CHD or stroke (WHO, 2011a). It is not confined solely to the developed world, it is the leading cause of death in developing countries too; low and middle-income countries account for almost 80% of all CVD deaths (Deaton et al., 2011, WHO, 2005).

The first evidence of a correlation between physical activity and CHD was found by observing the contrast in incidence of heart attacks amongst bus conductors and bus drivers (Morris et al., 1953). Drivers, sitting still for the majority of their shift, were almost twice as inclined to suffer a heart attack as conductors, who walked up and down the bus-stairs all day. The article reported that similar findings were made when comparing highly active postmen and their sedentary mail-sorting colleagues.

Many of the later studies were reviewed and meta-analysed by Berlin and Colditz (1990). They concentrated more so on leisure-time activity as opposed to the now less common, heavy occupational activity. The overriding consensus was that physical activity had a positive influence on the reduction of the incidence of coronary heart disease. The study also concluded that physical inactivity was a very significant risk factor for CHD, comparable to smoking and high cholesterol.

A more recent study investigating the association between physical activity and a combination of cardiovascular disease risk factors in children was carried out as part of the European Youth Heart Study (Andersen et al., 2006). The CVD-associated risk factors measured in this large sample of 9 and 15 year olds were blood pressure, triglyceride, cholesterol, insulin resistance, sum of four skin-folds and aerobic fitness. The study reported that those children in the lower physical activity quartiles were at significantly increased risk of having clustered CVD risks compared with their physically active counterparts. These findings led to the conclusion that children need to be more physically active to prevent the early onset of a wide number of CVD-related risk factors.

Although cardiovascular disease does not usually appear until well into adulthood, children are still susceptible to the development of CVD risk factors, risk factors that can lead to significant health problems in adulthood. The primary CVD risk factor that children and adolescents are likely to experience is obesity.

2.2.1.4 Diabetes

Type 2 diabetes, also known as non-insulin-dependent diabetes mellitus (NIDDM), is amongst the top five causes of death in the Western world, with the prevalence of the disease rising faster in the developed world than in the developing world (Hossain et al., 2007). It is characterised by insulin resistance and currently accounts for around 95% of all cases of diabetes worldwide (CDC, 2011). There is mounting evidence to suggest that a physically active lifestyle may help to prevent the onset of the disease. Physical activity was recently highlighted by the World Health Organisation as one of the key components in the prevention of type 2 diabetes (WHO, 2004). There is also strong evidence to suggest that physical activity, in the form of exercise, can be employed to improve insulin sensitivity and glucose intolerance (Ivy et al., 1999).

Large-scale cohort studies have been carried out in adult populations in the US investigating the development of diabetes for both men (Manson et al., 1992) and women (Hu et al., 2001). Both of these studies began with study samples that were free from type 2 diabetes. They then recorded their physical activity levels over a number of years and also recorded the prevalence of diabetes over time. Both studies reported that the prevalence of the disease was significantly higher in less active adults. This remained the case even when results were adjusted for obesity levels, the primary cause of type 2 diabetes. These findings support the theory that leading a physically active and healthy lifestyle is key to the prevention of type 2 diabetes.

Looking specifically at children, Schmitz and associates (2002) investigated the association between physical activity and insulin sensitivity, a key component of type 2 diabetes mellitus. The study involved 357 10-16yr olds, none of whom had diabetes. Physical activity was measured using a self-report survey. It was presented as kilocalories per day and participants were categorised into physical activity quartiles. Insulin sensitivity was measured by noting the amount of glucose required to achieve euglycemia after a night of fasting. Fasting insulin levels were also recorded. Significant correlations were reported between physical activity and both fasting insulin levels ($r=0.12$, $p=0.03$) and insulin resistance ($r=0.13$, $p=0.001$). Although this was a cross-sectional study, the author believed that these results were consistent with the finding of adult studies that increased physical activity may reduce the risk of type 2 diabetes.

A recently produced review has also confirmed the findings of Schmitz's study (Tompkins et al., 2011). This review concentrated specifically on studies that investigated the effect of physical activity on insulin resistance, specifically without any dietary intervention. The review provided further evidence that physical activity can positively affect the risk of type 2 diabetes. As stated by the author, future strategies for the prevention of type 2 diabetes should place a strong emphasis on increasing physical activity levels in children.

2.2.1.5 Morbidity and Premature Mortality

There is significant evidence suggesting that physical activity can help people live longer, reducing morbidity and having a positive influence on all-cause mortality. Observing the physical activity habits of subjects over the course of around 20 years, Paffenbarger and associates (1993) noted those that increased their activity levels over time tended to have a lower mortality rate than those that did not. In a comprehensive 2008 meta-analysis of studies investigating the relationship of physical activity on cardiovascular and all-cause mortality, the author found that activity provided a protective effect in both instances (Nocon et al., 2008). Both risks were reduced by approximately one third.

2.2.2 Psychological Health Benefits

The benefits of physical activity are not restricted to anatomical and physiological gains; they can be mental, emotional and social too. In terms of mental health, there is evidence to suggest that physical activity is inversely related to depression (Motl et al., 2004), as well as both anxiety and stress (Norris et al., 1992, Strauss et al., 2001). However, the dearth of long-term studies suggests there is a lack of evidence regarding causality.

2.2.2.1 Depression

In the largest adolescent-specific study investigating the relationship between physical activity and depressive symptoms, Motl and associates (2006) gathered self-report physical activity data from 4,594 children from the USA aged between 12-14 years. Subjects also reported on depressive symptoms through a 20 item questionnaire. This information was gathered again 2 years later and comparisons were made to establish changes in physical activity and the prevalence of depressive symptoms. The findings of the study suggested that a positive change in physical activity was inversely related to depressive symptoms in this sample. The strength of the relationship was weakened when accounting for confounding factors, but it still remained significant. Again, causality could not be inferred, intimating that depression may have led to a reduction in physical activity and not the other way around. Similar findings have been reported in a smaller scale study (Sanders et al., 2000), suggesting that moderate to high sports involvement is significantly related to a reduced prevalence of depression.

Causality was explored in an intervention-based study by Norris and associates (1992). An initial examination revealed that self-reported physical activity was positively associated with reduced depressive symptoms amongst the 147 participants. An intervention was introduced whereby participants were assigned to an aerobic training group (10 weeks of two 25minute training sessions), a flexibility training group and a control group. Comparing the association between activity and mental well-being before and after the intervention, significant benefits associated with the aerobic training were observed. Participants from that group reported being less stressed, and were much less likely to associate stress with depressive symptoms.

Longitudinal studies, investigating the association between activity and depressive symptoms in increased detail, are currently lacking. While causality and confounding factors, particularly obesity and self-efficacy, need to be considered, there is much evidence to suggest a significant correlation between physical activity and depression in young people.

2.2.2.2 Anxiety, stress and self-esteem

There has been less research regarding the health benefits of physical activity for anxiety, stress and self-esteem. Using accelerometers, Strauss and associates (2001) measured physical activity levels of a group of ninety-five 10-16 year old for a week. Self-efficacy was also examined using a combination of two scales, the Piers-Harris Children's Self-Concept Scale and the Revised Children's Manifest Anxiety Scale. The study showed that those who spent more time in high and moderate intensity activity (75^{th} percentile and above versus the 25^{th} percentile and below) were less inclined to have self-efficacy issues. The study failed to account for important confounding factors, particularly obesity, which may also have an important effect on how children and adolescents view themselves. This is an important concept, given that some studies have reported evidence of a significant association between physical activity and obesity (Duncan et al., 2006, Vincent et al., 2003).

Other studies have also found that the use of sport as a source of success can have positive effects on self-esteem and self-perception (Fox, 2000, Gruber, 1986). Fox claimed that activity, particularly sport, is positively associated with self-perception, including body image, from late adolescence onwards. Tremblay and associates (2000) conducted a cross-sectional study to investigate the relationship. Physical activity data was gathered from 5,146 Canadian school students using self-reported questionnaire. Self-esteem was also established via questionnaire, along with socioeconomic status (SES). Physical activity was significantly associated with improved self-esteem. The strength of this association was increased when focussing on high intensity activity. The association did not seem to be weakened when accounting for SES, and was similar for both boys and girls. Given the scale of the study, involving over 5,000 school students, it provides significant evidence that physical activity is positively associated with self-esteem.

Norris and associates (1992) investigated the association between physical activity and stress in 147 adolescents through the use of an intervention. Firstly, all subjects self-reported their physical activity and stress levels. At this stage, the author noted that the more active adolescents reported experiencing less stress. Subjects were then assigned to one of three different groups (moderate intensity training, flexibility training and a control group) for 10 weeks. At the end of the intervention, those adolescents in the high intensity training group reported having much lower levels of stress than the other groups.

All of these studies provide evidence of the positive effects of physical activity. While weight status is significant potential cofounding variable in this relationship, physical activity seems to play a positive role in terms of improving self-esteem and self-perception, as well as anxiety and stress.

2.2.2.3 Academic Performance

There is evidence to suggest that physical activity can have a positive effect on academic performance too. Academic performance is assessed by test results or indirectly by measures of concentration, memory, and classroom behaviour. A number of studies have noted that by adding physical education to the school curriculum, there have been positive improvements in academic performance (Sallis et al., 1999, Dwyer et al., 1983). Another study conducted by Shepherd (1997) investigated the effects of the addition of physical education to the curriculum. The study found that it did not have any negative effect on academic performance, despite the fact that the academic curriculum was reduced to allow for the extra PE classes. This suggests that there was a relative increase in academic performance per unit of time. The same study also reported that the addition of PE classes had a positive effect on general classroom behaviour. Other studies have reported that physical activity has a positive influence on concentration and memory for children (Caterino and Polak, 1999, McNaughten and Gabberd, 2003, Brisswalter et al., 2002, Tomporoski, 2003).

2.2.3 Developing Active Lifestyle Habits

As previously mentioned, the health problems associated with inactivity and sedentary behaviour tend to change and develop from childhood through to adulthood (see figure 2.1). The onset of the majority of chronic diseases such as cardiovascular disease and type II diabetes may not occur until adulthood, but the risk factors associated with them can develop in childhood. Outlined above are reasons why the promotion of physical activity at an early stage can be beneficial, providing many physical and psychological benefits. However, it is particularly important to note that the gains associated with being physically active in young life can be carried through adolescence into adulthood.

Similarly, physical activity patterns established in youth have been found to track into adulthood (Kelder et al., 1994, Telama et al., 2005, Taylor et al., 1999). As a result, active children are more inclined to be active adults, at a reduced risk of adult-onset chronic diseases. This adds evidence to the argument that it is particularly important to establish good physical activity habits at a young age.

Central to the promotion of physical activity in youth, from early childhood through to adolescence, is the theory that physical activity patterns can be tracked throughout life. This implies that physical activity patterns developed at a young age will determine, to some extent, adult physical activity behaviour. Given that evidence suggests that physical activity is associated with obesity, a cardiovascular disease risk factor, the idea that activity behaviour can be tracked from childhood into adulthood is a very important theory. It could potentially have some serious repercussions in terms of the design of interventions and public health policies aiming to promote physical activity as part of a healthy lifestyle. If physical activity is tracked into adulthood, interventions and policies need to target sedentary behaviour and inactivity as early as possible.

Many longitudinal studies have investigated whether or not activity tracks from childhood to adulthood, establishing if a person's relative ranking in terms of activity level is maintained over a significant period of time. Tracking is measured by gathering comparable longitudinal data on at least two dates and establishing the strength of the correlation (Pearson or Spearman's rank order) between the repeated measures. Physical activity patterns can also be tracked using percentiles and risk analysis. The strength of the correlation, and evidence of tracking, is affected by the length of time between repeated measures. This is particularly true when physical activity is determined subjectively by self-report questionnaire, as is the case in the vast majority of this type of study. For example, given a two-week gap between initial reporting of physical activity and follow-up, it stands to reason that subjects would not report a significant change in their behaviour, including physical activity habits. However, if the follow-up did not take place until five years later, the likelihood of subjects reporting the same physical activity patterns again is less likely. Their lifestyle, behaviour and physical activity habits will have changed, and these changes will be considerably more pronounced during the transition from childhood into adolescence and then on into early adulthood.

Considering these concepts, Janz and associates (2000) conducted a study investigating physical activity tracking in childhood with a view to improving the effectiveness of physical activity programs to combat sedentary behaviour in later life. A group of 10 year olds completed self-report questionnaires documenting physical activity. This information was gathered four times annually for 5 years and the results were compared using a Spearman rank correlation coefficients. As expected, physical activity tended to decrease with age for both boys and girls. The tracking coefficient for physical activity dropped from 0.52 to 0.32 for boys and 0.65 to 0.43 for girls, across the five years of the study. The sedentary behaviour tracking coefficient went from 0.56 to 0.48 for boys and 0.59 to 0.16 for girls. According to Malina (1996), a correlation of 0.3 to 0.6, covering the majority of these outcomes, is deemed to be moderate to high. This suggests that physical activity behaviour, in terms of both activity and sedentary behaviour, was maintained from ages 10 to 15 for both boys and girls. In fact, highly sedentary boys at baseline were 2.2 times more likely to be sedentary after five years compared to their active peers. The study also recorded physical fitness across the five years and reported similar trends as physical activity. The author concluded that children seemed to establish long-term physical activity patterns at a young age, boys slightly before girls.

While Janz investigated the tracking nature of physical activity from late childhood to adolescence (10 – 15yrs), Telama and associates aimed to investigate six baseline age groups (3, 6, 9, 12, 15, 18yrs), totalling over 2,300 participants . After baseline activity measurements were recorded, follow-up information was gathered 5 times over the course of next 21 years. A total of 2,309 provided information at baseline, and 1563 provided information after 21 years. The study also aimed to investigate the importance of specific activity type in terms of tracking. Did participation in organised sport at a young age affect the likelihood of organised sport participation in adulthood? Or was a child that partook of vigorous intensity activity, establishing a high level of fitness early in life, more likely to become an active and fit adult?

Again, Spearman rank correlation coefficients were recorded, comparing the baseline activity findings (from a self-report questionnaire) with each of the five follow-ups. The strength of the correlation decreased as time passed, although it remained moderate throughout for boys. The tracking coefficient ranged from 0.33 to 0.44 for boys and 0.14 to 0.24 for girls. The findings suggested that a high level of physical activity from a young age predicted similar physical activity behaviour in adulthood. The correlation was quite low for girls, although this might be explained by the fact that significant events in early adulthood, having children and getting married, may affect a woman's lifestyle, and physical activity habits, more than it would a man. The study also failed to find any patterns that supported the hypothesis that physical activity tracking is linked to specific types of activity in youth. The author concludes that all children can experience short and long-term benefits from partaking of any form of physical activity from a school age.

2.3 TRENDS IN PHYSICAL ACTIVITY IN THE UK

Statistics regarding physical activity trends amongst children in the UK tend to be produced primarily from the annual Health Survey for England (HSE), compiled by the National Health Service (NHS). The most recently published findings come from the 2008 Health Survey for England (2008), which focussed primarily on physical activity and fitness. Data was gathered using both subjective self-report measures and accelerometers, although there was little difference between the findings of the two methods.

The main finding of the survey was that physical activity levels were worryingly low for children in the UK. According to self-report measures, 32% of boys and 24% of girls, aged 2-15 years, reached current physical activity recommendations. The data collected from accelerometers, from a sub-sample of the total population, put these numbers at 23% for boys and 21% for girls. Of concern, this suggests that children had a tendency to over-estimate how active they were. The recommendations used as a cut-off point were those proposed by the Chief Medical Officer (CMO) in the 2004 Department of Health report 'At least 5 a week: Evidence on the impact of physical activity and its relationship to health' (CMO, 2004). In the report, the CMO recommended that children partake of at least 60 minutes moderate to vigorous activity daily. This is significantly higher than recommendations for adults, recommending they do at least 30 minutes of activity, three times per week. The 60 minute guidelines stemmed from the findings of the 2002 Health Survey for England (Sproston and Primatesta, 2003) in which physical activity was measured using a questionnaire that had not been validated. Children were asked how many times per week they partook of 60 minutes activity. Of all the subjects involved in the study (11,692), from ages 2-15, 70% partook of the recommended levels of activity, and 77% of 11-12 year olds reached the guidelines too. This information was established via interview, a subjective method that is not universally validated. The findings of this report suggest there has been a massive reduction in physical activity levels in the space of 6 years, although the possibility of inconsistent measurement methods should be considered as a new self-report questionnaire was piloted for the 2008 HSE.

Another government paper, the NHS report 'Statistics on obesity, physical activity and diet, 2010' (NHS, 2010) reported further findings from the HSE 2008. Forty-nine percent of boys and 38% of girls participated in formal activity, although the figures were considerably higher, 90% for boys and 86% for girls, for informal activity. Formal activity refers to organised exercise and sports. Looking in more detail at the commute to and from school, highlighted in the report as a good opportunity to increase activity, the report states that 63% of boys and 65% of girls walked to school at least one day per week. Only 5% of boys and 2% of girls cycled to school. More encouragingly, 95% of children reported partaking of some physical education during the school week.

The key findings from the 2008 Health Survey for England are that only 32% of boys and 24% of girls reached current physical activity recommendations. These statistics are of considerable concern. This is compounded by findings presented in the recent government report on physical activity, 'Be Active, Be Healthy: a plan for getting the nation moving' (2009a) placing the UK outside the top 20 in terms of physical activity when compared to other developed countries.

2.4 PHYSICAL ACTIVITY RECOMMENDATIONS FOR YOUNG PEOPLE

As stated above, in 2004 the CMO provided physical activity recommendations for children and adults. The specific guidelines for children recommend that they complete at least 60 minutes moderate to vigorous activity every day of the week. These recommendations are also supported by the World Health Organisation (WHO) and the Centre for Disease Control and Prevention (CDC).

One of the primary reasons for such recommendations, as discussed in more detail in section 4.3, is the fact that physical activity is a significant factor in terms of combating child obesity and related cardiovascular diseases (Grund et al., 2000). Physical activity is an important and modifiable element of all energy expenditure, thus influencing the energy balance equation and weight management (Spiegelman and Flier, 2001). Child obesity levels have risen in recent years (Jackson-Leach and Lobstein, 2006, Wang et al., 2008), a trend that has developed in tandem with the current shift towards decreasing levels of physical activity amongst young people (Andersen et al., 1998, Goran, 1997).

Bearing in mind these associated issues, it is important to ensure that children and adolescents are participating in sufficient physical activity to ensure they lead healthy lives. In order to achieve enough activity, baseline recommendations are required. Having specific physical activity recommendations for young people is essential as it helps establish if children and adolescents are active enough and also provides them with defined, achievable and measurable physical activity targets.

To date, the majority of physical activity, and in particular step count, recommendations have been aimed at adults and older people. Guidelines for young people have been unsophisticatedly derived from those of their adult counterparts. Further still, adult physical activity guidelines have not been validated, based on unsubstantiated claims and following that, norm-referenced values. As a result, the history of step count recommendations for children is particularly contentious and warrants detailed analysis.

2.4.1 Early recommendations

Prior to 2004, not much research exists regarding physical activity recommendations for young people. The earliest recommendation was a catch-all figure of 10,000 steps per day, failing to distinguish between children and adults or males and females. This figure originated in Japan in the 1960's as part of a promotional drive for walking clubs (Hatano, 1993). There was no empirical evidence applied to establish this figure. The specific source and development of 10,000 is not known, although it has been suggested that they may have stemmed from norm-referenced step count values taken around this time (Tudor-Locke et al., 2008). There does not seem to be much in the way of research-based justification for the figure, it was simply an easy-to-remember, round and also attainable number. This recommendation was developed primarily for adults as opposed to children, it was only applied to them too for the sake of convenience.

Ten thousand steps was the accepted general recommendation for everyone from the 1960's up until the start of the 21st century. In 2001, the President's Challenge Physical Activity and Fitness Awards Program became the first to recognise that out-dated, adult-centred, catch-all activity recommendations may not be applicable to young people (USDHHS, 2001). Subsequently, child-specific guidelines appeared for the first time. Performing a secondary analysis on data collected for an alternative study, Vincent and Pangrazi (2002) proposed step count guidelines of 11,000 and 13,000 steps for boys and girls, respectively. These figures were norm-referenced, established simply by getting the mean values for boys and girls from the data.

There were some obvious limitations associated with this method. Eleven thousand and 13,000 steps refer solely to the average amount of steps taken by a group of US children. There is no evidence to suggest that this is the requisite number of steps needed for a healthy lifestyle. It is not widely accepted that step counts are correlated with any measure of health or well-being, such as body composition or fitness. Although this group of boys may take an average of 13,000 steps per day, they may also be overweight or obese.

In the UK, activity guidelines were published in 2004 by the Chief Medical Officer (CMO, 2004), stating that to lead a healthy life, young people should take part in at least 60 minutes of at least moderate physical activity per day. These guidelines were developed with a view to managing weight and improving musculoskeletal and cardio-respiratory function, with an emphasis on the lifestyle benefits of activity. Again however, these guidelines were established without any proof that they were actually related to any health, and specifically weight management, benefits. More importantly, they were time-based recommendations. There were no step count-specific guidelines being developed in the UK.

By 2004, there were two main, government-endorsed sets of physical activity guidelines for young people. In the US, children were encouraged to take 11,000 and 13,000 steps per day for girls and boys, respectively. In the UK, it was recommended that all young people partake of at least 60 minutes of moderate activity per day. These recommendations were developed with a view to ensuring that young people lead healthy lifestyles, including maintaining a healthy weight status. But both sets of guidelines were based on the mean activity levels of a sample of subjects from populations that were, as has widely documented, getting more and more obese at an alarming rate, the prevalence of obesity having tripled amongst adolescents since 1980 (Freedman et al., 2007).

2.4.2 Criterion-referenced recommendations

The first study to use markers of health as a reference for activity guidelines was published by Tudor-Locke and associates (2004). Criterion-referenced guidelines were established by comparing physical activity, as defined by step counts, to weight status, as defined by body mass index (BMI). Using this methodology, the authors aimed to establish more accurate and beneficial step count guidelines. In effect, these new guidelines were to be established based on their likelihood to elicit specific health benefits, in this case, maintaining a healthy BMI.

A secondary analysis of data from a previous study by Vincent and associates (2003) was conducted. One thousand, nine hundred and fifty four US children of varying ethnicity, ranging in age from 6-12 years old, were included. The ethnic breakdown was as follows; 53% White, 30% Hispanic, 4% Native American, 3% African American, 2% Pacific Island/Asian and 8% other. Four weekdays' physical activity data was gathered. Researchers visited the children every single morning at school to record how many steps they had taken in the preceding 24 hours. Children also filled out a daily survey to establish whether or not they had worn their pedometers for the full 24 hours. If a child did not wear their pedometer for at least 23 hours, all data for that day was disregarded. This increased the accuracy of the step count data.

The criterion-referenced cut-off points method can only be used if there is an actual significant difference between the contrasting groups. In this case, the two groups were those considered normal weight and those considered overweight or obese as defined by BMI (Cole et al., 2000). A significant difference ($p<0.001$-0.048) between the normal and overweight groups was observed. The optimal age and gender-specific standards were calculated based on a combination of four statistical indices: (1) the probability of correct decisions; (2) misclassification of errors; (3) validity coefficient; (4) utility analysis.

The probability of correct decisions (1) refers to the probability of correct classification (true normal/overweight/obese) versus the probability of incorrect classifications (false normal/overweight/obese); where the cut-off point matching with the highest score is deemed optimal. Misclassification of errors (2) is the likelihood of incorrectly classifying someone as active or inactive from BMI. Errors occur when either a) a normal weight individual does not achieve the steps/day cut point and is incorrectly classified as overweight/obese (type I), or b) when an overweight individual achieves the steps/day cut point and is therefore incorrectly classified as normal weight (type II). In this instance, the most fitting cut-off point is the one that corresponds with the lowest score.

The validity coefficient (3) measures the accuracy of the relationship between BMI and weight status. In this instance, the cut-off point corresponding to the highest validity coefficient has the highest probability of correct decisions. Utility analysis (4) provides an estimate of the expected maximum utility for a given cut-off point. First, expected disutility, the expected loss (misclassification from the ‘’true overweight/obese’’ status) associated with a given cut point, and expected utility, the sum of the proportions of both error types after assigning weights to these misclassifications, are measured. Type I and Type II errors can potentially occur here. The sum of expected disutility and utility is represented as expected maximum utility. This figure is multiplied by the sample size of the combined groups, and the largest resulting value indicates the optimal cut-off point for classifying weight status by steps/day.

To select the final BMI-referenced standard according to both sex and age group, all of statistical indices simultaneously (i.e., a higher probability of correct classifications, a lower probability of incorrect classifications, a higher validity coefficient, lower expected disutility, and higher expected utility) were considered together. Finally, the median of all optimal steps/day cut points for 6–12 year olds was computed for each sex.

The 1,000 step increments presented here (table 2.2) were considered to provide sufficient precision for measurement. An easily remembered round figure was also deemed beneficial for motivational purposes. The study concluded that young people between the ages of 6-12 should take 12,000 and 15,000 steps per day for girls and boys, respectively.

Table 2.1 - Step/day cut-off points for boys and girls (Tudor-Locke et al., 2004)

	Steps/day			Steps/day	
Age	**Boys**	**Girls**	**Age**	**Boys**	**Girls**
6	15,000	12,000	10	14,000	13,000
7	16,000	12,000	11	16,000	11,000
8	17,000	10,000	12	14,000	11,000
9	15,000	13,000	Median	15,000	12,000

The only other study to date, that investigated physical activity recommendations for young people was carried out by Duncan and associates in New Zealand (2007a). This study aimed to develop and hopefully improve upon the step count recommendations that had previously been defined by Tudor-Locke. The overall methodology, criterion-referenced guidelines based on contrasting groups, was the same as that used by Tudor-Locke. However, with a view to improving accuracy, the study differed in two ways.

Whereas Tudor-Locke's previous recommendations were based on weekday data only, this study used both weekday and weekend step count data. The use of weekend data is based on the findings of previous studies that children take less steps on the weekend than during the week (Duncan et al., 2006, Rowe et al., 2004). Secondly, the criterion-reference parameter used in this instance was percentage body fat (%bf), as opposed to BMI used in the study by Tudor-Locke. This second change was based on findings from another study carried by Duncan reporting that step counts had a stronger association with %bf than with BMI (Duncan et al., 2006). This was explained by the fact that %bf is a more accurate measure of adiposity than BMI, as BMI is not sensitive to the differences between lean and fat mass (WHO, 95) (see section 4.2). Ultimately, it was hoped that these new step count recommendations would have a closer association with important health outcomes such as adiposity.

The study by Duncan conducted a secondary analysis of data from a previous study, also carried out by the author in New Zealand in 2006 (Duncan et al., 2006). It involved 969 children, between the ages of 5-12 years, with mixed ethnic composition; European (50%), Polynesian (29%), Asian (17%) and 4% of other ethnicities.

Percentage body fat was established through the use of bioelectrical impedance analysis and body composition classification was based on international BMI cut-off points (Cole et al., 2000). Physical activity was established using a New Lifestyles NL-2000 pedometer. The same contrasting groups method, as used in the study by Tudor-Locke and associates (2004) and described above, was used.

The results of the study proposed that the optimal step count cut-off points for girls and boys are 13,000 and 16,000 steps, respectively. The author commented that the previous guidelines developed by Tudor-Locke and associates (2004) were reasonable targets but still needed to be increased by 1,000 steps for both genders, suggesting that it is a worthwhile increase in daily activity for improved health outcomes. The variation between the results of the two studies can be explained by the slight differences in the methods used. Contrasting evidence exists regarding the significance of the association between step counts and BMI. Also, children are less active at the weekend, a fact that was unaccounted for in the previous study. With this in mind, it may be necessary to increase the daily guidelines to account for the drop-off in activity over the weekend.

2.4.3 Cross-Validation of Recommendations

Subsequently, two studies (Beets et al., 2008, Laurson et al., 2008a) have since investigated the accuracy of the recommendations developed by both Tudor-Locke and Duncan. Beets and associates (2008) aimed to cross-validate the current BMI-referenced step count guidelines proposed in the study by Tudor-Locke and associates. This study followed on from the recommendation suggested in the study by Duncan that population specific step count guidelines need to be developed to account for the varying demographic characteristics of different population samples.

This particular study gathered data from three previous studies in California, North Carolina and Arizona. Data was gathered from 1,067 children, ranging in age from 6 to 12 years of age with an ethnic breakdown of 81% White, 14% Hispanic and 5% from other ethnic backgrounds. Data was taken from any 4 full days in a 7 day period.

Results were compared with Tudor-Locke's guidelines to establish whether these US children compared favourably with the recommendations. However, the compared results showed that step counts did not differentiate between normal and overweight US children. Thus, the usefulness of Tudor-Locke's recommendations was questioned. A possible reason given for this is the inherent limitations of using pedometers to measure physical activity, particularly differing intensities of activity. The author cited the hypothetical situation of two boys, one obese and one a healthy weight, that take 12,000 steps per day. While the obese boy just walks at a slow pace to accumulate the 12,000 step total, the healthy boy does 2 hours of vigorous training, a high intensity activity. Although they have similar step count readings, the healthy boy expends a great deal more energy, thus exposing the limitation of the pedometer. The author also cited the use of BMI-defined weight categories as another possible reason for error, a point also highlighted by Duncan. It is also worth noting that the relationship between obesity and physical activity is not a simple one. While they may be related, one is not directly correlated to the other; there are many important confounding factors to be considered. Physical activity does indeed play an important role in influencing a child's adiposity levels, however it is just one of a great number of factors involved.

The author concluded, like Duncan had previously done, by questioning the effectiveness of blanket guidelines for all child populations. Given that pedometer-determined activity was not an accurate indicator of weight status, the author suggested that current recommendations needed to be used with some caution, or preferably be replaced by population and ethnicity specific guidelines.

The other study aiming to cross-validate pedometer-determined criterion-referenced activity guidelines for young people was conducted by Laurson and associates (2008a). The author noted that a widespread consensus on step count recommendations was lacking. This study aimed to employ receiver-operating characteristic (ROC) analysis to measure the specificity and sensitivity of Tudor-Locke and Duncan's step count cut-off points. At the same time, ROC-derived recommendations could also be established.

One thousand, three hundred and seventy young people, aged between 6 and 12 years old, took part in the study. The vast majority of participants were white (92%). Weight status was established by BMI and classification was consistent with recommendations from the International Obesity Task Force (IOTF) (Cole et al., 2000). Seven days of pedometer activity was recorded. Step count recommendations were established using ROC analysis; the plotting of a curve showing sensitivity versus 1–specificity.

The cut-off points developed using ROC analysis were 9,983 for girls and 13,666 for boys. Both sets of previous recommendations had high levels of sensitivity but low levels of specificity. Between 55-75% of the subjects in this study reached current recommendations. This poor performance can be somewhat explained by the fact that the sample of children involved in this study were all from the USA, a country with particularly poor rates of physical activity intensity (Vincent et al., 2003).

The author noted that the results of Tudor-Locke's data may be slightly skewed as the majority of the subjects were from Sweden and Australia, countries where activity levels are high. Therefore, these recommendations may not be applicable to subjects from less active countries, like the US. From this study, the authors concluded that, much like the other studies before it, caution is needed when applying these guidelines to specific populations and ethnicities.

2.4.4 Considerations for Future Research

Tudor-Locke and associates (2004) highlighted that the study was a preliminary investigation of step count recommendations and should be cross-validated using an independent sample before being accepted universally. Both Tudor-Locke and Duncan (2007a) carried out secondary analyses of data collected from quite specific population samples. Thus, they may not be applicable to all young people, particularly when considering populations of different or varying ethnicities. Both studies conclude that population-specific step count guidelines may be warranted. This suggestion is supported by two studies (Beets et al., 2008, Laurson et al., 2008a) carrying out cross-validation of Tudor-Locke and Duncan's guidelines.

A great deal of progress has been made in the last five years developing tailor-made step count recommendations for young people. Where once, there were only unsupported catch-all recommendations for adults applied to children, now there are gender and age-specific guidelines available for children and adolescents. At this point, the step count recommendations developed by Tudor-Locke and associates (2004) are more widely applied and can effectively be employed for comparisons across studies.

However, it seems evident that caution should be taken when employing the step count guidelines developed by either Tudor-Locke or Duncan. Physical activity is affected by a wide variety of determinants and these also need to be considered. Further research is warranted to cross-validate these recommendations, with a view to potentially confirming or denying the guidelines' sensitivity and specificity in a wide range of child population.

CH. 3 – MEASURING PHYSICAL ACTIVITY

3.1 THE IMPORTANCE OF MEASURING PHYSICAL ACTIVITY IN YOUNG PEOPLE

As discussed in section 2.2, there are many health-related benefits of physical activity for young people. These can be short-term and long-term benefits, and encompass both physical and psychological benefits (Strong et al., 2005). They concern important health-related issues, from morbidity due to non-communicable lifestyle diseases (Andersen et al., 2006) to premature mortality. Given the important role that activity plays in terms of leading a healthy life, increasing physical activity is now considered to be as important a factor as tobacco control, promoting a healthy diet and obesity prevention in minimising the risk of non-communicable diseases and possible premature mortality (Mathers et al., 1999). The World Health Organization recognised the important role played by physical activity in the recent report 'Global Strategy on Diet, Physical Activity and Health' (WHO, 2004), highlighting the need to promote physical activity as part of a healthy lifestyle.

3.1.1 Purpose of Measuring Physical Activity

The primary aim of measuring physical activity is to enhance our understanding of it. By monitoring and measuring it, we can improve our knowledge of the determinants and factors associated with physical activity (Welk et al., 2000). In doing so, improved and refined health promotion plans can be developed and implemented, better employing physical activity as part of a healthy lifestyle. The effectiveness of plans and activity interventions can then be gauged through physical activity measurement (Bauman et al., 2006). The primary benefits of physical activity measurement are outlined below.

i. Understanding the relationship between physical activity and physical and mental health outcomes in epidemiological research: Studies investigating the association physical activity and health outcomes are necessary as they help to fully determine the significance of physical activity (Ekelund, 2004, Welk et al., 2000). Cross-sectional, cohort and case-control epidemiological studies, measuring physical activity levels in conjunction with the prevalence of specific health outcomes, are employed for this purpose. By carrying out such studies, the specific nature of the relationship between activity and lifestyle diseases can be ascertained.

ii. Monitoring physical activity levels amongst specific cohorts: Once the exact relationship between physical activity and serious health outcomes is better understood, this emphasises the importance of being physically active. It is thus important to monitor the physical activity levels of the general population. In doing so, those specific sections of the population highlighted as failing to reach current physical activity guidelines can be identified. These cohorts can thus be identified as at-risk groups for serious non-communicable diseases (Ekelund, 2004, Heath et al., 1993).

iii. Understanding the determinants of physical activity: By measuring physical activity levels, we can improve our knowledge of its determinants and factors (Ekelund, 2004). Identifying these determinants is key to understanding why some people are physically active and others inactive. For example, physical activity can be measured in conjunction with environmental factors to establish if issues like housing, socio-economic status or access to green spaces affect activity levels. This knowledge furthers our understanding of physical activity and aids the development of well-informed interventions.

iv. Establishing the effectiveness of health promotion plans and physical activity interventions: Once physical activity levels and their determinants have been established, well-informed plans and interventions can be developed, specifically tailored to improve physical activity levels (Ekelund, 2004, Heath et al., 1993). The ability to accurately measure physical activity enables researchers and health care professionals to judge how effective their interventions are.

v. Developing a strong evidence base for wider health promotion policies and practices: All of the benefits mentioned above can be employed to develop our understanding of physical activity in the wider context of health promotion. By identifying the determinants of activity, those at risk of inactivity and the success of interventions, physical activity can be better employed as a health tool to tackle non-communicable diseases. The accurate measurement of physical activity is thus very important to effective health promotion (Welk et al., 2000).

3.1.2 What Dimensions of Activity to Measure?

Physical activity covers a wide range of bodily movement, from typing a sentence on a keyboard, through walking to the bus stop, to completing a triathlon. Activity has both mechanical and metabolic properties (Haskell and Kiernan, 2000). The mechanical component of activity refers to the movement itself, be it a static or a dynamic contraction of muscle that results in movement. The metabolic component refers to whether the activity is aerobic (requires oxygen) or anaerobic (does not require oxygen).

Physical activity is also categorised by a number of dimensions; type, intensity, duration and frequency. As a result, there is no one particular tool that can accurately measure all types and dimensions of physical activity (Goran, 1998). A wide variety of different possible methods of measurement have thus been developed. These methods vary in terms of their validity, reliability and feasibility. Criterion (gold-standard) methods are available that can track certain components of physical activity. Direct observation can record every minute of activity that a person does, also noting the approximate intensity of that activity. It was developed specifically with children in mind (Welk et al., 2000). Calorimetry can give precise information regarding the amount of energy that is expended as a result of physical activity, thus accurately predicted the intensity. However, before deciding on a method of measurement, it is important to consider what exact components of activity you intend to measure.

Referring again to the definition of physical activity, it is described as movement leading to increased energy expenditure (EE) (Caspersen et al., 1985). Accordingly, there are to two main components of activity, movement and energy expenditure, and two ways in which it can be quantified; by measuring the amount of movement a person does or by measuring the amount of energy that they expend. While energy expenditure can provide accurate information regarding frequency, intensity and time, it fails to provide information regarding the context of the physical activity (Ekelund, 2004). This information is necessary to understand the specific behaviour that leads to this energy expenditure.

Depending on the aim of the research, recording a person's movement may be more relevant. Along with data regarding frequency, intensity and time, information can also be gathered regarding the context of the activity. Depending on the measurement tool, details pertaining to the type of movement, sport or activity can be gathered. Physical activity measurement tools can provide information on pedometer-determined steps, accelerometer-determined motion, heart rate activity and both self-report and direct observation-determined minutes in specific forms of activity. These methods also provide insight into the specific activity patterns and behaviour, information not provided through the measurement of EE.

Choosing the most suitable method of physical activity measurement for a study is primarily influenced by the research question (Ekelund, 2004). A study may aim to investigate physical activity levels in a specific cohort. This is a very loose idea. The specific aims of a study will influence what type of measurement tool is employed. For example, if the aim of a study is to investigate physical activity levels in schoolchildren with a view to providing interventions to increase these levels, certain specific information needs to be gathered. First, the magnitude of activity needs to be measured. All methods of measurements provide this, with varying degrees of accuracy and detail (Ekelund, 2004). However, in this instance it may also be worth noting when exactly children are active: in the classroom or the schoolyard; during school hours or after school; during the week or at the weekend. This information could be very useful in terms of targeting specific times during the week when activity interventions are most needed. Establishing this information depends upon the use of one of a select few measurement tools.

It is worth noting that the focus of health promotion has shifted from the assessment and management of individual activity to changing social and environmental factors in larger cohorts. Physical activity is widely heralded as a key component to a healthy lifestyle (WHO, 2004). This shift highlights the need for the measurement of activity at a population level (Sallis and Owen, 1999). This is another important consideration when choosing a measurement tool. Highly detailed, cost and labour-intensive methods are being shunned in favour of cheaper methods capable of observing activity in large samples.

3.1.3 The Unique Physical Activity Patterns of Young People

When choosing a method for physical activity measurement, it is extremely important to consider and understand the specific population that the method is to be applied to. Specifically, the demographics of the test cohort and the purpose of the data both need to be considered (Welk et al., 2000). For instance, the methods employed may differ depending on whether a study involves children or adult participants; especially given the unique nature of childhood activity patterns.

Bailey and associates (1995) carried out an observational study amongst a group of 6 to 10yr olds with a view to understanding their physical activity-related behaviour. Observations were recorded every 3 seconds over a period of 12 hours, thus provided an in-depth insight into the group's activity patterns. Overall, the group spent 77% of their time in low intensity activity, compared with 3.1% of their time in high intensity activity. High intensity activity was maintained for a median of 3 seconds at a time, and 95% of high activity was less than 15 seconds in duration. The median time between bouts of high intensity activity was 18 seconds, with 95% of all rest periods less than 4 minutes 15 seconds. This data presented a picture of sporadic bouts of high intensity activity coupled with longer rest periods in between.

Understanding the prevalence of this behaviour, deemed to be biologically pre-determined in all species (Rowland, 1998), should influence the method of measurement employed for studies involving children. The measurement method needs to be sensitive to the unique nature of childhood physical activity patterns.

3.1.4 Other Considerations

AS well as the research question, the method of measurement of physical activity is determined by other factors, including the resources available and the feasibility of the method (Ekelund, 2004). Particular considerations need to be made when the study is investigating physical activity in young people. For example, concerns regarding reliability are increasingly warranted. As outlined in section 3.2, younger children lack the ability to accurately recall their behaviour. Employing laboratory-based techniques, such as doubly-labelled water and indirect calorimetry, may also lead to logistical and ethical issues when trying to measure activity in children. Given that children lack independence, being under the supervision of a school or guardian the majority of the time, it would prove significantly more difficult to organise testing.

It is also important to consider the resources available when deciding on a measurement approach for physical activity. Cost and manpower are key considerations too (Ekelund, 2004). There are gold standard methods available for the measurement of both energy expenditure (doubly labelled water technique) and movement-determined physical activity (direct observation). However, it is not always practical or feasible to employ either of these methods. The doubly labelled water technique is extremely costly, while direct observation is very labour-intensive. As a result, neither method is suited to a large-scale epidemiological study. Budget constraints should be acknowledged in the context of the scale of the study. A £500 study budget to measure how active one child is will lead to a significantly different methodology to a £2000 budget to investigate activity levels amongst 40 children.

The key to the successful measurement of physical activity in young people is finding a measurement tool that balances validation, reliability and accuracy with a practically feasible option relevant to the cohort and your aims (Dugdill et al., 2009). In doing so, our understanding of activity patterns amongst young people can be furthered, which is ultimately beneficial to health promotion.

3.2 METHODS OF MEASUREMENT

The most commonly employed methods of measuring physical activity in children are discussed in detail below. They include both indirect methods, which rely on some degree of subjective interpretation on the part of the person recording the activity, and direct methods. Direct methods are objective measures of physical activity, recording a specific unit of activity that does not require any interpretation (Portney and Watkins, 2000b). Also discussed is the gold-standard method of physical activity measurement, direct observation. Although the doubly labelled water method and calorimetry (indirect and whole room) are sometimes described and employed as criterion measures against which other methods of activity measurement are compared, specifically they are measures of energy expenditure as opposed to physical activity (Schoeller et al., 1986). The main advantage and disadvantages of these different methods are presented in table 3.1.

Table 3.1 – Advantages and Disadvantages of Common Methods of Physical Activity Measurement

	Advantages	Disadvantages
Direct Observation	• Gold-standard method • High reliability • High validity • Extensive info provided - frequency, duration, intensity & type	• Extensive training required • Labour intensive (time/cost) • Reactivity
Self-Report Measures	• Cheap • Suitable for large-scale studies • Extensive info provided - frequency, duration, intensity & type	• Recall bias • Poor validity • Poor reliability
H.R. Monitors	• Affordable • Objective method • No training necessary – data easily interpreted • Moderate validity at higher intensities • Provided info on frequency, duration & intensity	• Based on flawed linear relationship • Unreliable below threshold • Unsuited to child activity patterns • Requires individual calibration
Accelerometers	• Objective method • Provided info on frequency, duration & intensity • Suitable to free-living environment • High validity • High reliability	• High cost • Compliance issues • Potential reactivity • Lost data
Pedometers	• Objective method • Cheap • Ease of use/interpretability • Suitable to free-living environment • High validity • High reliability	• Lack info regarding intensity • Compliance/reactivity concerns • Lost data

3.2.1 Indirect Methods

3.2.1.1 Direct Observation

Direct observation of a person's movement is deemed to be the 'gold standard' method of activity measurement (Sirard and Pate, 2001). It is seen as the criterion method of measurement, used for comparative purposes to determine the validity of other methods. Given that this method requires a researcher to observe and interpret movement, it is classified as a subjective measure of physical activity.

Direct observation involves trained researchers observing and recording levels of physical activity over a specified period of time. A structured system of recording is usually used, with specific codes corresponding to different characteristics. The information gathered can include frequency, intensity, duration and type of activity. Environmental (e.g. whether the activity took place indoors or outdoors) and social (e.g. whether the activity involved other children or adults) contextual factors can also be recorded. Typically, only one child is watched at a time by the researcher. The observation period can vary greatly, from 30-40min lessons to a full day.

Two of the most commonly used recording systems are the Children's Activity Rating Scale (CARS) (Puhl et al., 1990) and the Children's Physical Activity Form (CPAF) (O'Hara et al., 1989). These focus primarily on activity intensity. CARS has been validated against both indirect calorimetry (a gold standard method of measurement for closely related energy expenditure) (Puhl et al., 1990) and accelerometers (Finn and Specker, 2000). Puhl and associates also established very high inter-rater reliability for direct observation. The Fargo Activity Timesampling Survey (FATS) has also been validated against indirect calorimetry (Bailey et al., 1995). This method, which gathers information on duration, frequency and intensity of activity, also displayed high inter-rater reliability.

Given its high validity and reliability, direct observation is definitely useful as a validation criterion (Corder et al., 2008). However, a number of substantial disadvantages suggest that it has practical limitations and may not be suitable for the measurement of free-living physical activity at a population level. As previously mentioned, researchers need to be trained in this method and regular inter-observer reliability tests are necessary. In addition, researchers are required to spend extensive periods of time carrying out field testing (Pate et al., 2010). This can be burdensome in terms of time and money. The very nature of direct observation means that it is also something of an invasion of privacy for study participants. It stands to reason that reactivity may be a feasible concern too. The issue is relatively unreported for children. However, in the study by Puhl and associates (1990), less than 20% of children involved in the study reported being aware of the presence of those observing them.

Direct observation is established as the optimum method for the measurement of physical activity, primarily as a result of the scope and detail of information that can be gathered from it. With well-trained and monitored researchers, it is also highly valid and reliable. The contextual factors gathered using this method help to create an in-depth and highly informative picture of the behaviour element of the physical activity in children. This information could be very useful in terms of understanding the determinants of activity. Unfortunately, it is time-consuming, expensive and reliant on highly trained researchers. As such, it is an unrealistic method when trying to investigate physical activity levels of a large group of people. Whilst effective in a controlled environment (e.g. classroom or schoolyard), direct observation may also prove difficult when trying to observe children accurately in a free-living environment.

3.2.1.2 Self-Report Measures

Self-report measures of physical activity have traditionally been the activity measurement method of choice in large-scale study of children in a free-living environment (Pate, 2010). They are low in cost and can easily be used on large study samples over a short period of time. These measures include self-report questionnaires, diaries, reports, surveys and questionnaires. They can also be proxy measures; reports or questionnaires completed by the parent or teacher of the study's participant (Corder et al., 2008). Depending on the specific method employed, a wide range of information can be gathered from self-report measures; duration, intensity, frequency and also context, mode and determinants of physical activity (Corder et al., 2008).

The effectiveness of these methods depends on both the ability of the participant (or proxy) to recall their activity levels and also the perception of the person reporting to record the information correctly. As participants, children are thus at something of a disadvantage; their ability to recall can be negatively affected by linguistic and cognitive limitation compared to adults (Corder et al., 2008, Sirard and Pate, 2001). With this in mind, it is widely reported that self-report measures of physical activity, particularly diaries, are not suitable for children under the age of 10 (Pate et al., 2010, Sirard and Pate, 2001).

Recall bias is a concern for children and adults alike, undermining the validity of self-report activity measures. Due to the erratic nature of childhood activity, children can often underestimate how active they have been (Sallis, 1991), while adults tend to overestimate how active they are. Corder and associates (2008) performed a review of studies investigating the validity of self-report measures. Overall, interview-administered reports seemed to be more reliable than self-administered reports, although all measures were poorly correlated with accelerometers. Welk (2007) reported a correlation of r = 0.21 for self-report via interview and r = 0.31 for an activity log. Burdette and associates (2004) reported similarly poor associations. The use of an activity checklist completed by parents achieved a correlation of r = 0.33 while recall by parents was even less effective, with a correlation of r = 0.20 reported between parental recall and accelerometer-determined activity.

Sirard and Pate (2001) also reviewed the validity of different-self measures of activity and reported consistently similar findings. The one exception to this was a group of studies from the Family Health Survey in the mid-1980's. In a bid to validate self-report measures of activity against direct observation, Baranowski (1984) reported levels of agreement between 73-86%. Sirard and Pate did remark that in terms of self-reported methods, Janz et al (1995) reported especially poor results (r = 0.17) because the study participants were less than 10 years old.

The review also looked at the validity of questionnaire interviews, noting that the strength of reported correlations varied greatly across studies (r = 0.1 – 0.89). The authors concluded that questionnaires recalling multiple days of physical activity proved too difficult for children; only one day of recall or 'usual' activity was recommended. The least effective subjective measure seemed to be proxy reporting (r = 0.04 – 0.19). This seemed to hold true for both parents and teachers (Noland et al., 1990). The author argued that parents and teachers lack the ability to accurately account for and recall all child activity, particularly outside of the household or classroom. Children engage in short and sharp bursts of activity, that even they have trouble remembering and thus recording (Corder et al., 2008).

Telford and associates (2004) investigated the validity of a physical activity questionnaire in young people by comparing it against an accelerometer. The author was particularly interested in finding a single questionnaire that could measure type, duration and frequency of physical activity. They noted that previous studies claiming the ability to record intensity were using one or two day recall surveys. Such a study design would warrant significantly increased labour and administrative costs, undermining the advantages of self-report methods.

Telford employed the Children's Leisure Activities Study Survey (CLASS), a questionnaire upon which the Youth Physical Activity Questionnaire (YPAQ) and Children's Physical Activity Questionnaire (CPAQ) are based. It included proxy and self-reported activity from a typical week. The data gathered from this questionnaire was compared with accelerometer data gathered from each child (n=169). Participants were either 5-6 years old or 10-12 years old. Two age brackets were included as younger children are less inclined to engage in structured or organised activity.

The convergent validity between self-report and proxy-report was high amongst the older group, although the correlation for moderate-to-vigorous physical activity (MVPA) and total physical activity was poor. Criterion validity, investigating the correlation between minutes per day accelerometer physical activity and minutes per day questionnaire physical activity was poor. The mean difference between accelerometers and proxy-reported total activity was 141 minutes per day for 5-6 year olds and 11 minutes for 10-12 year olds. The mean difference for self-report was just 1.5 minutes per day. Spearman's correlations between accelerometers and both questionnaires indicated poor criterion validity, ranging from 0.02 to 0.24.

Telford concluded that the proxy method provided the most reliable measure of type, duration and frequency of physical activity. However, neither the self-report nor the proxy-report could provide a valid measurement of total physical activity, particularly physical activity intensity. This limitation may be explained by the fact that the conversion of questionnaire data into actual physical activity intensities is based on guidelines developed for adults. No such conversion guidelines exist for children, undermining the accuracy of this method of measurement. Corder (2008) also questioned the accuracy of activity intensity estimations for children based on energy costs of specific activities for adults. The author also proposed another potential limitation of self-report measures for the measurement of activity intensity. Children's activity is both sporadic and spontaneous, and this type of activity is difficult to report using weekly, daily or even hourly recall. As a result, short bursts of vigorous activity, common amongst children, may go unnoticed.

The investigation of the validity of self-report methods for the measurement of physical activity was revisited in a systematic review conducted by Foley and associates (2012). Unlike previous studies, this review looked specifically at the validity and reliability of 'use-of-time' reports for children, more detailed questionnaires that record both physical activity and sedentary behaviour. However, many of the findings from this review are relevant to traditional self-report questionnaires.

Sixteen studies were included in the review, employing six different 'use-of-time' reporting tools. Validity and reliability of these tools were generally found to be moderate, validity ranging from r = 0.30 to 0.40. The range in validity across studies was primarily explained by differences in sample age and recall time. One-day recall led to higher validity compared to three-day recall. As mentioned above, one-day recall warrants significantly increased labour, time and administrative costs. Such limitations actually undermine the advantages usually associated with self-report methods.

3.2.2 Direct Methods

3.2.2.1 Heart Rate Monitoring

Heart rate monitoring can also be employed as a measure of physical activity, seeing as there is a linear relationship between physical activity and heart rate in steady state exercise (Pate et al., 2010, Haskell and Kiernan, 2000). Using a heart rate monitor that can record and store minute-by-minute average heart rate data, physical activity intensity, duration and frequency can be estimated. Physical activity intensity can be determined by establishing either arbitrary or pre-determined thresholds for time spent above certain heart rate intensities.

The relationship through which heart rate measures activity levels is not a direct one, it is in fact the supposedly linear relationship between heart rate and energy expenditure. Heart rate rises in tandem with the increased relative stress on the cardiopulmonary system, caused by the expenditure of energy (Rowlands et al., 1997). Usually, the increased energy expenditure is a result of physical activity. Therefore, a raised heart rate represents an increase in activity. However, this relationship is flawed for a number of reasons. As pointed out by Rowlands and associates (1997), cardio-respiratory response is affected by type of exercise (e.g. static or dynamic) and also the muscle mass involved. Completing a repetition of heavy weight training may elicit a similar reaction to heart rate as a 400m race, but the physical activity of these two actions may vary greatly.

Another limitation is the fact that the relationship between heart rate and energy expenditure is not a constantly linear one. While the relationship does become approximately linear at moderate and vigorous activity intensities, this is not the case at lower intensity activity (Corder et al., 2008). Below a certain 'flex point', changes in heart rate that could be attributable to changes to activity intensity cannot be differentiated from other possible cofounding environmental factors (e.g. stress, anxiety). Any other stimuli that raise heart rate will lead to an overestimation of physical activity (Pate et al., 2010).

Bearing in mind that the accuracy of heart monitoring decreases significantly below a certain threshold, Corder and associates (2008), amongst other researchers (Riddoch and Boreham, 1995), concluded that heart rate monitoring can only reliably measure moderate to vigorous intensity activity. Riddoch and Boreham applied an arbitrary threshold of 120 beats per minute for moderate intensity activity. Therefore, any sustained period of time during which 120bpm or less were recorded by children in the study, the data should be discounted as unreliable. Unfortunately, it has been reported that children do not often stray above 120bpm. In a study employing heart rate monitors for activity measurement, Freedson (1989) found that amongst young people, between 60 and 75% of recorded heart rate data was below the 120bpm threshold. This may be explained by the erratic 'stop start' nature of young people's physical activity behaviour (Welk et al., 2000).

There is no universally accepted protocol for the application of heart rate monitoring to physical activity measurement. In one respect, this is not as much of an issue as with other methods such as direct observation. Heart rate is an established measure and thus, comparison between studies should be easier (Corder et al., 2008). However, it is not a simple case of recording and presenting heart rate data, it must be converted to an interpretable format of activity intensity. Given that it is largely an arbitrary value, the threshold applied for varying levels of intensity differs greatly between studies.

The establishment of accurate thresholds for varying levels of heart rate-determined activity intensity is a considerably difficult task. To be truly representative of the activity levels of the participant being researched, initial individual calibration is necessary (Pate, 2010). This is done by observing and recording the relationship between heart rate and oxygen consumption (VO_2). This test should be undertaken in a laboratory, with VO_2 being measured using indirect calorimetry. The reaction of heart rate to incremental changes to energy expenditure is closely monitored. As a result, the body's expected heart rate at certain activity intensity levels can be recorded and these values used as the thresholds.

Calibration of individual activity intensity thresholds is particularly important with a view to accounting for variations in fitness and obesity levels between study participants. When individual calibration is employed in a study, heart rate monitoring has been validated against the doubly labelled water method (Livingstone et al., 1992). However, when not calibrated in a study employing heart rate monitors to measure physical activity, Maffeis and associates (1995) discovered that physical activity levels were massively overestimated amongst obese participants. This may be explained by an observation made by Saris (1985), that fitness levels affect heart rate. Fitness is closely associated with obesity. Fit children tend to have a higher stroke volume, leading to a lower heart rate. The heart rate thresholds between fit and unfit or healthy and obese children may be significant. Thus, if not individually calibrated, it will seem that fitter children, with lower resting heart rates, will seem to be less active than their less fit, or obese, counterparts.

Unfortunately, given individual calibration is so burdensome, particularly in large-scale studies, it is not widely practiced. A review of heart rate monitor studies found that only 5 of 20 studies individually calibrated thresholds for interpretation of heart rate data (Riddoch and Boreham, 1995).

Another important consideration is the response lag associated with heart rate. It does not increase immediately in response to the sudden changes in activity that are typical of childhood behaviour (Bailey et al., 1995). Time is required for heart rate to adapt to the physical activity intensity. As a result, heart rate monitor-determined physical activity could potentially be under or over-estimated due to response lag.

Heart rate monitoring is a cost-effective, objective measure of moderate and vigorous activity that can, in theory, be employed effectively in large-scale studies of young people. However, unless individual calibration takes place prior to testing, its validity as a measure of physical activity remains questionable.

3.2.2.2 Accelerometers

Accelerometers are motion sensors, similar to but slightly more sophisticated than pedometers. They measure acceleration caused by bodily movement in one (usually vertical) to three plains (Pate et al., 2010). While pedometers record movement using a spring mechanism, accelerometers do so using piezo-electric transducers and a microprocessor to convert the accelerations into activity counts (Sirard and Pate, 2001). Accelerometers can provide information regarding frequency, intensity and duration of activity, although lack the ability to record context. Activity counts can be recorded at pre-determined time intervals ranging from 1 second to 1 hour.

According to both Sirard and Pate (2001), brand, placement, activity and inter-participant variations all need to be considered when deciding whether to use accelerometers for activity measurement. They reviewed the validity and reliability of a number of brands of accelerometers, along with other motion sensors. Included in the review were the Caltrac, Actigraph and TriTrac brand accelerometers. The Caltrac and Actigraph are similar models of unilateral accelerometer. They measure acceleration in the vertical plain and remain the most popular accelerometers employed in research today. The TriTrac accelerometer measures movement in three plains. In establishing validity across 4 separate studies, the review found that the older Caltrac accelerometer had a positive but highly variable association (r = 0.16 – 0.80) with direct observation. The newer model accelerometers reported higher criterion validity against direct observation and whole room calorimetry (r = 0.69 – 0.93) in 5 studies reviewed.

Another, more recent review from de Vries and associates (2006) looked at the validity and reliability of nine different brands of accelerometer, including the most popular Actigraph and TriTrac models. Intra-instrument reliability was consistently reported as good, increasing from r = 0.45 to 0.80 for 1 to 8 days (Mattocks et al., 2007). Criterion (versus a gold standard method) and construct validity (versus other validated methods of measurement of activity) were both analysed across ten studies. Accelerometers were found to be valid when compared with direct observation (r = 0.90) (Hands et al., 2006), indirect calorimetry (Trost et al., 2006, Schmitz et al., 2005) and other motion sensors (r = 0.72) (Kelly et al., 2004). The TriTrac model performed particularly well when compared with other monitors and the doubly labelled water method (r = 0.81 – 0.88) (Ramirez-Marrero et al., 2005). This review concluded that once a reputable brand of accelerometer was used in research, it was a valid method of measurement of physical activity levels in children. The differences in the validity and reliability of the different brands of accelerometer was not consistent or sufficiently compelling enough for the author to state which was the best brand of accelerometer.

Accelerometers have many benefits; they are easy to use for both the participant and the researcher and they are widely reported to be a valid method of childhood physical activity in a field-testing environment. They can provide more information than pedometers in the way of minute-by-minute data regarding activity. They do have some minor limitation; compliance, loss of data, an inability to register some activity (particularly for unilateral accelerometers). The main consideration associated with accelerometers is the cost. The models reviewed by de Vries (2006) ranged in price from $300 to $4700. Purchasing large quantities of accelerometers for a large-scale study, allied to the risk of loss or damage to them along the way, potentially places a considerable financial burden on researchers.

3.2.2.3 Pedometers

Pedometers are another form of motion sensor designed to objectively measure physical activity. Pedometers are cheap, easy to use devices that provide a reading of steps. Typically, they measure steps by using a spring-suspended mechanical lever that moves up and down in response to vertical displacement (Pate et al., 2010) or using a piezo-electric mechanism. This mechanism, deemed more accurate, has a horizontal cantilevered beam with a weight on the end which compresses when subjected to acceleration, generating voltage oscillations that are used to record steps (Crouter et al., 2005).These steps can then be displayed digitally. Pedometers can also provide a number of derived output readings. These vary depending on the brand, and include distance travelled, calories expended and time spent at specific activity intensities (Tudor-Locke et al., 2009). These additional features are estimates derived from step counts and have not been validated amongst children.

The basic reading provided by pedometers, step counts, do not need to be calibrated, unlike heart rate monitors. However, pedometers do have some disadvantages that have limited their use and effectiveness in research. While they provide a daily total of step counts, they fail to provide information on intensity, duration or context of activity. They may also be affected by improper placement, reactivity or the gait length of participants. A complete literature review of the validity of pedometers is presented in section 3.3.

3.2.3 Choosing The Most Suitable Method For The Current Study

The main advantages and disadvantages of the most common methods of physical activity measurements are presented in table 3.1. Given the complex and heterogeneous nature of physical activity, it is difficult to precisely measure all of its dimensions (type, duration, frequency, intensity) using a single measurement tool. Recent technological advances have lead to the production of increasingly sophisticated physical activity measurement tools. Amongst these is the Viper pod (StatSports Technologies, Ireland), which has gained popularity as an activity feedback tool in professional sports. The Viper pod, worn around the upper back in a specially designed garment, contains a tri-axial accelerometer, three dimensional gyroscope and digital compass, GPS, heart rate monitor and long range radio (Statsports, 2012). These components can log data 100 times per second and this data can be received wirelessly up to two football pitches away. This data is automatically processed and presented in a wide variety of parameters; speed, distance, heart rate, dynamic stress load, number and magnitude of accelerations and decelerations.

While this technology is predominantly employed by professional sports teams, providing in-depth real-time feedback of performance, it may also have benefits in terms of public health research. Ultimately however, this tool fails to report all dimensions of physical activity. Some other method, either self-report or direct observation, is required to establish the exact type of activity that was performed. This may not be an issue in a professional sports' context, wherein all activity is monitored and specific time periods can be referenced against pre-planned activity timetables. It would, however, be a problem in epidemiological research conducted in a free-living environment. Like accelerometry, in order to provide detailed information regarding all dimensions of physical activity, it would need to be combined with other methods of physical activity measurement. Another potential limitation is the high cost associated with such cutting-edge technological tools.

Therefore, when choosing a measurement tool, compromises need to be made, leading to the loss of some information (Goran, 1998). However, with the technological advances and the level of interest in the promotion and measurement of physical activity in recent years, a number of highly reliable and validated methods are available to measure physical activity levels amongst young people. The advantages and disadvantages of the most common methods are outlined above (table 3.1). Depending on the nature of the research, any of these methods could potentially be successfully used.

Choosing a measurement method for a study is primarily influenced by the research question that the study aims to answer. The research question and aims must be considered in the context of the resources available for the study and inevitably, some level of trade off will be required (Ekelund, 2004). The choice must combine validity, reliability & accuracy with a tool that is practically feasible given the aims, nature and resources available for the study (Dugdill et al., 2009).

As mentioned in chapter 1, the current study aims to investigate physical activity levels across a large sample of Year 7 students in Tower Hamlets. All of the 2,600 Year 7 students in Tower Hamlets will be invited to participate in the study, the design of which includes recording a cross-sectional measurement of physical activity levels. Activity will be recorded for one week. Physical activity is being recorded amongst these schoolchildren for a number of the reasons outlined in section 3.1.1: monitoring physical activity levels amongst this cohort; understanding the determinants of physical activity in this particular cohort; understanding the relationship between physical activity and positive health outcomes; gathering evidence for wider health promotion policies and practices. The study aims to treat physical activity as a behavioural issue as opposed to a physiological property, reporting findings regarding the physical activity patterns of a large cohort instead of detailed energy expenditure figures for individual participants. This is allied to the increased emphasis in activity research on the measurement of physical activity at a population level (Sallis and Owen, 1999). All of these issues need to be considered when choosing a suitable method of physical activity measurement.

Aside from the aims of the study, consideration must also be given to the resources available for the current study. These issues will play an important role in determining the most suitable and feasible choice of measurement tool. All physical activity testing will be conducted by a single investigator over the course of two school years, immediately constraining the manpower and time available for testing. This will influence the choice of method. For example, the employment of direct observation is too time-consuming when hundreds of children must be tested by a single investigator. The current study also has a limited budget so the high cost of certain equipment may also prove a prohibitive factor.

A rough calculation of the number of units required to conduct all testing can be conducted to provide estimated costs associated with different methods. There are approximately 2600 Year 7 students in the fifteen secondary schools in Tower Hamlets. Over two years, assuming all students participate, 1300 students must be tested each year. Testing is possible during approximately 35 of the 52 weeks in the year, accounting for holidays and examinations. This equates to 37 students per week, or 74 per fortnight. A typical testing cycle, involving the distribution of an activity monitor, 7 days measurement, returning the monitor and processing the data, would take roughly two weeks. Therefore, the study would require at the very least, assuming none are lost or broken, 74 activity monitors. Previous and pilot research suggests that monitors will be lost and broken. A conservative estimate means that the study requires 100 activity monitors to feasibly measure the activity levels of all potential students. A standard pedometer costs approximately £50, while a tri-axial accelerometer costs £200. Purchasing 100 units would increase the study budget cost by £5,000 and £20,000 for pedometers and accelerometers, respectively.

Both of these potential constraints, a workload beyond the limitations of a single investigator and the extensive costs associated with technologically-advanced measurement tools, can be addressed by employing self-report measures, heart rate monitors or pedometers. However, all of these methods do have limitations, most outlined in section 3.2. As discussed in section 3.2.1.2, self-reporting of physical activity, particularly amongst children, is negatively affected by potential recall bias as well as linguistic and cognitive limitations. More importantly, previous studies suggest that self-reported physical activity measurements can be unreliable and inaccurate, with children more inclined to underestimate how active they are (Sallis, 1991). Proxy reporting seems to increase the problem (Noland et al., 1990). Researchers suggest that accuracy is improved by getting participants to report on one previous day's activity or on 'usual' activity (Sirard and Pate, 2001). As a result, self-report is not a viable option for the reporting of physical activity patterns of children over a sustained period of time, as is planned for the current study.

While heart rate monitors satisfy a number of the criteria for this study, they are also affected by reports of inaccuracy below a certain threshold (Corder et al., 2008), undermining their validity (see section 3.2.2.1). Riddoch and Boreham (1995) applied an arbitrary threshold of 120 beats per minute, below which children's heart rate data should be discounted as unreliable. This can be improved but requires that each monitor is individually calibrated (Maffeis et al., 1995). The increased workload associated with this practice ensures that heart rate monitors are not feasible for a study of this size and nature.

It is not possible to accurately measure all components of physical activity with just one measurement tool (Goran, 1998). As a result, pedometers' inability to record activity intensity remains an issue. Bailey and associates (1995) reported on the nature of child activity patterns, marked by short burst of high intensity activity, followed by extended periods of low activity, and this should be considered when choosing a tool as well. Neither self-report methods nor pedometers can record this type of behaviour; pedometers because they provide only a single step count total at the end of the each day, and self-report because children lack the ability to accurately recall specific activity patterns over a sustained period of time.

The use of accelerometers could also address this issue, as they can provide minute-by-minute information regarding activity intensity. However, as stated earlier, accelerometers remain prohibitive because of their high cost (de Vries et al., 2006), an accelerometer being at least four times as expensive as a pedometer (approx. £50 versus £200). Using accelerometers would require a budget of £20,000, which is greater than that available for the current study. However, the use of pedometers is compatible with the both the design and the budget of the study, costing approximately £5,000.

Pedometers have repeatedly been found to be a valid measurement tool of free-living physical activity for children, as discussed in significantly more detail in section 3.3. They are easy to use, enabling researchers to gather data from a large number of people at one time. They are also relatively inexpensive and are compatible with the budget of the current study. The output provided by pedometers, daily step counts, also provides an advantage over other methods. Step counts can easily be understood and interpreted by both the subject and the researcher. There also exist universally accepted step count recommendations for children (see section 2.4), used to calculate rates of activity/inactivity and provide feedback and motivation to subjects.

Pedometers do have certain limitations, as discussed in more detail in section 9.6. However, having considered the specific aims of the current study in combination with the advantages and disadvantages of the most common methods of physical activity measurement, pedometers were deemed the most appropriate method for use in the current study.

3.3 VALIDITY OF PEDOMETERS IN YOUTH

The effective measurement of physical activity amongst children and adolescents, for both intervention and observational studies, and in monitoring and promoting physical activity with a view to countering the obesity epidemic, is of great importance. One of the more commonly used and readily available methods of physical activity assessment is the pedometer.

Given their low cost, pedometers are practical for use in large-scale epidemiological studies. They have the potential to be a very useful method of measuring activity and provide valuable information to potentially counter obesity. However, as with all evaluation tools, their effective use is dependent on pedometers being validated as an accurate and reliable determinant of physical activity levels. Previous studies have been conducted reviewing the validity of pedometers. However these have differed in that they have investigated a number of different methods of physical activity measurement (de Vries et al., 2006) or looked at the validity of pedometers amongst adults (Tudor-Locke et al., 2002). This section aims to review all published papers investigating the validity, reliability and feasibility of pedometers as determinants of physical activity amongst children and adolescents.

3.3.1. Methods

3.3.1.1. Search strategy

The electronic databases PubMed, Web of Science, PsycINFO, CINAHL and SportDiscus were used to search for articles that satisfied the inclusion criteria. The search was limited to articles from 1990 to the present date, given that the technology used in pedometers is constantly evolving and the current technology only began being reported in the mid 1990s. The specific search strategy consisted of three unique searches of similar terms, separated by the Boolean term OR: “pedometer OR pedometers OR pedometry”; “validity OR accuracy OR reliability OR feasibility OR reactivity”; “children OR adolescents”. These three separate searches were then combined using the Boolean term AND to gather all possible papers and prevent duplication. Results were compared across all five search engines and again, any duplicates removed. The titles and abstracts from all identified papers were assessed to determine their appropriateness for the research question. Full manuscripts of the articles deemed relevant and adhering to the inclusion and exclusion criteria were ordered. The reference lists of these papers were then cross-checked to identify any possible additional publications not previously found.

3.3.1.2. Inclusion and exclusion criteria

The inclusion criteria were:

- Studies reporting the validity, reliability, consistency or accuracy of pedometers and step count monitors
- Full text, English language publications
- Studies of males or females of any ethnicity between the age of 4-20 years

The exclusion criteria were:

- Case reports, editorials, comments, letters, abstracts and systematic and other review papers.
- Studies not looking at the accuracy, reliability, consistency or validity of pedometers
- Unpublished or non-English language publications
- Studies with adults or people with medical conditions as subjects

3.3.1.3. Data extraction and assessment

The data extracted from each paper included:

- Study design
- Sample size
- Population characteristics
- Main outcomes (r and ICC values)
- Relevant limitations

The effectiveness of pedometers amongst children was addressed under the following headings:

Validity: Convergent validity refers to the extent to which the output of one instrument correlates with the output of other instruments that should, theoretically, be measuring the same exposure of interest (Tudor-Locke et al., 2002). In this instance, the convergent validity of a pedometer can be ascertained by comparing it to self-report questionnaires, heart rate monitors and accelerometers; all of which measure physical activity. Criterion validity refers specifically to the comparison of a method to the most valid assessment method available, the gold or criterion standard (Tudor-Locke et al., 2002). There is currently no universally agreed upon method for physical activity measurement. There is a valid argument for a number of different methods, mainly direct observation, doubly-labelled water technique or indirect calorimetry (Mahar and Rowe, 2002). It is important for researchers to consider what element of physical activity they wish to assess. Direct observation is a better reference point in terms of step count measurement (Sirard and Pate, 2001) whereas the other two methods are more suited to the measurement of energy expenditure.

Validity can be quantified using Pearson's product-moment correlation coefficient (r). Other output measures of validity are percentage accuracy/error and interclass correlation (ICC). A general guideline is that an ICC greater than or equal to 0.75 is deemed good (Portney and Watkins, 2000f).

Reliability: This covers a number of similar concepts. Reproducibility or repeatability refers to the extent to which a pedometer is free of measurement error (de Vet et al., 2003). This covers both intra-instrument reliability which is the test-retest reliability of a pedometer, and inter-instrument reliability which refers to the variability between pedometers.

Feasibility: This refers to the cost involved and skill required when using a pedometer. Feasibility also includes acceptability, the tolerance of the device and amount of lost or missing data as a result of malfunctioning and any other limitations involved. Feasibility also covers the issue of reactivity, a change in normal behaviour as a result of having to wear a pedometer (Ozdoba et al., 2004). . True reactivity can only be gauged by knowingly and covertly measuring activity and comparing. Given this is practically unfeasible, most studies investigate the difference between the first and subsequent days of activity measurement

3.3.2 Results

3.3.2.1 Search strategy

The initial electronic search using the three main keywords, including variations led to the identification of 178 possible papers. Upon applying the inclusion and exclusion criteria as stated in the methodology, 38 articles remained. Fifteen papers were duplicates. Finally, upon reading through all of these papers and checking their bibliographies for other relevant papers, 25 papers were deemed suitable for this literature review and these are summarized in Table 3.2 below. Across the 25 studies reviewed here, a total of 13,692 children and adolescents were included as subjects. They ranged from 4 to 20 years of age.

Table 3.2 - Studies investigating the validity and reliability of pedometers

Author (Year)	Sample (n , age)	Methods	Results
Barfield et al (04)	71	5 days in-school activity – 2 pedometers (Yamax SW200) on hips	Inter-instrument reliability: ICC = 0.96-0.99
Beets et al (05)	20 , (5-11)	3 laps walking – 2 pedometers (Yamax SW200, Walk4life LS2505) vs. direct observation 5 speeds on treadmill – 4 pedometers vs. direct observation	Walking: Validity vs. d/o: ICC >/= 0.985 Bilateral variability: ICC >/= 0.33 – 0.99 with increasing speed Treadmill: Validity vs. d/o: ICC >/= 0.225-0.99 with increasing speed
Beets et al (06)	141, (8-10)	7 days activity – pedometer (Walk4life LS2505) vs. self report questionnaire	Reactivity: 78.5% of children noted reactivity, 47.3% of parents
Cardon et al (04)	92, (6-12)	6 days activity – pedometer (Yamax SW200) vs. questionnaire	Validity: r = 0.39
Craig et al (10)	10275, (5-19)	7 days activity – pedometer (Yamax SW200)	No reactivity between day 1 & 2 1 day provided reliability (ICC = 0.79) and validity (absolute % error = 2.5%)
Duncan et al (07)	85, (8-11)	3 speeds on treadmill – 2 pedometers (NL 2000) vs. direct observation	Error vs. d/o: 20 – 0.7% improves with increasing speed
Eston et al	30 , (8-11)	4 speeds on treadmill & play – 1 pedometer(Yamax SW200), 2 triaxial accelerometers, HR monitor	Validity vs. HR: Treadmill: ICC >/= 0.816 Play: ICC >/= 0.883
Graser et al (07)	77, (10-12)	2 x treadmill, shake test – 5 pedometers (Walk4life LS2505)	Accuracy: 99% Right side deemed best position
Jago et al (06)	78 , (11-15)	3 speeds on treadmill – 3 pedometers (Yamax SW200), uniaxial accelerometer	Reliability: ICC >/= 0.51-0.92 Bilateral variability: ICC >/= 0.73-0.8 Validity vs. accelerometer: r = 0.6
Kilanowski et al (99)	10, (7-12)	Recreation & classroom – pedometer (Yamax SW200), triaxial accelerometer, d/o	Validity vs. accel: r = 0.99/0.5 for rec/class Validity vs. d/o: r = 0.96/0.8 for rec/class
McDonald et al (05)	97 , (6-20)	3 days activity / treadmill – 1 HR monitor, 1 pedometer (Stepwatch 2) / direct observation	Validity vs. HR: r = 0.49 Validity vs. d/o: 99.7% accurate
Michaud et al (02)	233 , (11-15)	7 days activity – pedometer (Pedoboy), self-report	Validity vs. self-report: r = 0.15
Mitre et al (08)	27 , (11)	4 speeds on treadmill – 4 pedometers (Yamax SW200), 2 accelerometers, direct observation	Validity vs. d/o: 50% - 75% accurate, improving with increasing speed
Nakae et al (08)	394 , (7-12)	3 speeds on treadmill – pedometer (Kenz Lifecorder, Omron HJ7001T), direct observation	Validity vs. d/o: Significant measurement error for pedometers
Oliver et al (07)	13 , (4)	Free play – pedometer (Yamax	Validity vs. d/o: Significant

		SW200), direct observation 3 speed walking – pedometer, direct observation	measurement error for pedometers
Ozdoba et al (04)	45, (9-10)	4 days activity x2 – sealed vs. unsealed pedometer (Yamax SW200)	Reliability: ICC = 0.86-91 (sealed) and 0.85-0.91 (unsealed) – no reactivity
Ramirez-Marrero et al (04)	12	7 days of activity – pedometer (Yamax SW200), triaxial accelerometer, questionnaire and doubly-labelled water	Validity vs. accelerometer: r = 0.88 Validity vs. DLW: r = 0.67
Rowe et al (04)	299, (10-14)	7 days of activity – pedometer (Yamax SW200)	Reliability: r = 0.69-0.79 – no reactivity
Rowe et al (07)	296, (11-13)	6 days activity – self-report questionnaire vs. pedometer (Yamax SW200)	Validity: r = 0.17 – ped provided external validity
Scruggs et al (07)	288, (11-13)	PE class – pedometer (Yamax SW701, Walk4life LS2505) vs. Direct observation	Pedometer validity vs. d/o: r = 0.85-0.98
Scruggs et al (05)	257	PE class – pedometer (Yamax SW651) vs. direct observation	Accuracy: 98% Validity vs. d/o: r = 0.84
Scruggs et al (03)	369 , (7-8)	PE class – pedometer (Yamax SW200) vs. direct observation	Validity vs. d/o: r = 0.74-0.86
Strycker et al	367 , (10-14)	7 days activity – pedometer (Yamax SW701), self-report	Validity vs. self-report: r = 0.04 (at school), 0.15 (non-school), 0.25 (vigorous PA)
Treuth et al (03)	68 , (8-9)	4 days activity –uniaxial accelerometer, pedometer (Yamax SW200), 2 self-report	Reliability: ICC >/= 0.08 Validity vs. accelerometer: r = 0.47
Weston et al (97)	48, (12-14)	1 day recall vs. pedometer and uniaxial accelerometer	Validity: r = 0.88, pedometer provided external validity

3.3.2.2 Criterion validity

Twelve studies investigated the criterion validity of pedometers by comparing their performance to that of direct observation (Beets et al., 2005, McDonald et al., 2005, Mitre et al., 2009, Nakae et al., 2008, Oliver et al., 2007, Scruggs, 2007a, Duncan et al., 2007b, Graser et al., 2007, Kilanowski et al., 1999, Scruggs et al., 2003, Weston et al., 1997, Scruggs et al., 2005).

Beets and associates (2005) compared the accuracy of four different types of pedometers to direct observation by looking at the two across 5 speed grades and for all four pedometer brands used, the accuracy improves with increasing speed (ICC = 0.225-0.99). When asked to walk at a normal pace, no longer on the treadmill, subjects walked at approximately 67m.min^{-1}, the third of five paces. Duncan and associates

(2007b) presented similar finding, pedometers performing well at moderate and fast paces (0.7% measurement error) but underperformed at slower walking speeds (20% measurement error). Mitre and associates recorded a correlation between pedometer determined activity and directly observed activity ranging from 50% accurate to 75% accurate (Mitre et al., 2009), improving with treadmill speed in all cases.

In a free living environment, the correlation between pedometers and direct observation ranged from r = 0.8 (1999) to ICC = 0.985 (Beets et al., 2005) depending on the specific environment and activity that subjects were engaged in. In three studies conducted by Scruggs and associates (2003, 2005, 2007a) correlation coefficients with direct observation in a free-living environment ranged from 0.74 to 0.92. By investigating free-living physical activity as determined by a pedometer, Oliver and associates (2007) reported that it correlated poorly with direct observation. As a result, they do not recommend pedometers as an accurate measure of physical activity in children. McDonald and associates (2005) found pedometers to be 99.87% accurate when compared with 10 minutes of self-paced walking. Kilanowski and associates (1999) investigated the validity of pedometers in both a classroom and recreational setting. The findings showed a high correlation with direct observation in both instances (r = 0.8 (classroom), r = 0.96 (recreation)).

3.3.2.3 Convergent validity

Three studies measured the convergent validity of pedometers against heart rate monitors (Eston et al., 1998, McDonald et al., 2005, Weston et al., 1997). Six studies measured the convergent validity of pedometers against accelerometers (Jago et al., 2006, Treuth et al., 2003, Eston et al., 1998, Kilanowski et al., 1999, Weston et al., 1997, Ramirez-Marrero et al., 2005) and five studies measured the validity of pedometers against self-report measures (Michaud et al., 2002, Strycker et al., 2007, Cardon and De Bourdeaudhuij, 2004, Rowe et al., 2007, Treuth et al., 2003).

The level of correlation between pedometers and accelerometers ranged from 0.47 (Treuth et al., 2003) to 0.99 (Kilanowski et al., 1999) depending on environment and type of activity. Kilanowski and associates (1999) carried out testing in both a classroom and recreational setting, and found that pedometers and accelerometers were more strongly correlated in the recreational setting (r = 0.98) than in the classroom environment (r = 0.5), but combined results showed an even stronger correlation (r = 0.99). Jago and associates (2006) measured only moderate and vigorous activity levels when comparing the accuracy of pedometers and accelerometers. In doing so, the author found a positive correlation between both methods (r = 0.6), regardless of whether subjects were walking, walking fast or running.

Correlations with heart rate monitors ranged from r = 0.49 (McDonald et al., 2005) to ICC >/= 0.83, again dependant on environment (treadmill vs. free living) and activity type. Eston and associates (1998) also compared the accuracy of pedometers with heart rate monitors and correlations were established from treadmill activity and unregulated play activity. A stronger correlation was found during unregulated play (r = 0.883, 0.865, 0.762) than during treadmill activity (r = 0.816, 0.712, 0.319). The study also found that, along with the HR monitor, the pedometer was strongly correlated with SVO_2. McDonald and associates (2005) also concluded that a pedometer was a valid method of physical activity assessment in children, based on a moderate correlation between pedometers and HR monitors (r = 0.49).

Correlations between pedometer-determined activity and activity levels as determined by self-report and questionnaire ranged from r = 0.04 (Strycker et al., 2007) to 0.39 (Cardon and De Bourdeaudhuij, 2004). One study found a correlation between pedometers and the doubly-labeled water method of r = 0.88 (Ramirez-Marrero et al., 2005).

3.3.2.4 Reliability

The inter- and intra-unit reliability as well as inter-brand reliability of pedometers was investigated in eight of the studies (Beets et al., 2005, Jago et al., 2006, Treuth et al., 2003, Graser et al., 2007, Mitre et al., 2009, Eston et al., 1998, Barfield et al., 2004, Craig et al., 2010).

Barfield (2004), Beets (2005) and Jago (2006) investigated the reliability of pedometers, paying specific attention to bilateral variability; right vs. left placement. Beets did so using four different brands of pedometer and at five different speeds. Bilateral variability travelled in range from ICC >/= 0.33-0.99 depending on activity and speed of movement, increasing with speed. During walking, walking fast and running tests, Jago and associates had subjects wear three identical pedometers around their waists. Jago found that the degree of reliability amongst pedometers ranged from ICC >/= 0.51-0.92 and inter-unit reliability levels ranged from 0.73 – 0.8 (Jago et al., 2006). Once again, this variance in range was due to type of activity, fast walking deemed more reliable than running. Barfield recorded a very small range in reliability (ICC = 0.96-0.99), regardless of the setting.

Graser and associates (2007) asked subjects to wear five pedometers at once, 3 around the waist and 2 on the thigh. Mean percentage error at each site was established by direct observation. The right side of the waist was deemed the site with the lowest rate of pedometer inaccuracy (5.3%). Mitre and associates (2009) and Eston and associates (1998) also experimented by using more than one pedometer at a time. Mitre discovered a variation of between 3% and 10% depending on what side of the body the pedometer was worn. Both studies concluded that the use of just one pedometer, worn on the right side of the hip, was sufficient to give a valid reading of a child's physical activity levels.

3.3.2.5 Feasibility

The feasibility of pedometers, specifically looking at reactivity, was assessed in three studies (Beets et al., 2006, Ozdoba et al., 2004, Rowe et al., 2004, Craig et al., 2010). Ozdoba (2004), Craig (2010) and Rowe (2004) gauged reactivity based on the hypothesis that if the observed activity the first day(s) is not significantly different from activity levels on the last day(s), then reactivity has not taken place. In the study conducted by Rowe reliability improved as the number of days increased (r = 0.59–0.81). Ozdoba noted that this parameter varied from an ICC of 0.85 to 0.91, while Craig recorded an ICC ranging from 0.79 to 0.92. In the other study measuring reactivity, it took place for 79% and 47% of children, as observed by child and parent respectively.

Investigating the benefit of sealing pedometers, Ozdoba noted that seven unsealed pedometers had been tampered with and reset, compared with zero sealed pedometers.

3.3.3. Discussion

3.3.3.1 Criterion Validity

The most suitable gold standard method of physical activity, and specifically step count measurement, is direct observation. However, accurate direct observation over the course of one day would require the researcher to record every moment of a 24hr period in close proximity of the subject. This is very impractical in normal living circumstances and as a result, researchers try to find a more controlled environment to carry out observation. With this in mind, a more favorable environment for physical activity assessment by direct observation is on a treadmill. As a result, the criterion validity of different methods of physical activity assessment is often measured via a treadmill test. This review covers seven studies that assessed the validity of pedometers in this way (Beets et al., 2005, Duncan et al., 2007b, Graser et al., 2007, McDonald et al., 2005, Mitre et al., 2009, Nakae et al., 2008, Oliver et al., 2007).

Beets and associates (2005) and Duncan and associates (2007b) both noted that the accuracy of pedometers improved with increasing speed. Although the pedometer underestimated physical activity at a slower pace, this is an uncharacteristically slow pace for a child to walk at and not representative of their behavior in free-living environment. Duncan and associates proposed that this underperformance could be explained by the mechanics of the pedometer. A force of 0.35g is required to register a step on a pedometer (Melanson et al., 2004). Given that, at the slower paces, children are more inclined to take long, slow and controlled steps, they may not be achieving the required g-force, a theory supported by the findings of a recent study by Duncan and associates (2007b). As a result, pedometers underestimate physical activity levels when compared with direct observation. Mitre and associates (2009) and Nakae and associates (2008) also found that decreasing speed leading to decreasing accuracy could be attributed to insufficient acceleration and displacement.

Given that the pedometers were deemed valid indicators of physical activity at moderate and fast speeds, the practical significance of the poor correlations at lower speeds may not be relevant. Firstly, children do not travel at such a slow pace when walking. Secondly, it is moderate and vigorous activity that is required for children to attain health benefits, not slow walking. Therefore, it is most important that moderate and vigorous activity should be tracked by the pedometer. Despite the fact that pedometers were consistently inaccurate at the slowest speeds, the accumulated evidence suggests that they are highly reliable at more practical speeds.

However, the author does note that poor correlation may be in part due to the use of direct observation (Children's Activity Rating Scale), which was designed to measure energy expenditure, not physical activity. These are two very different variables and it is worth remembering that the sole function of a pedometer is to measure step counts, not energy expenditure. Also, the feasibility of direct observation in a free living environment is questionable and may have affected the results.

McDonald and associates (2005), Kilanowski and associates (1999) and Scruggs and associates (2005) recorded high levels of criterion validity during self-paced walking, a recreational setting and PE class, respectively. The consistent accuracy of pedometer data compared with direct observation in these and other studies (Graser et al., 2007, Scruggs, 2007a, 2007b), even in a free-living environment, gives further weight to the argument that it is a valid method of activity measurement. In both recreational and more sedentary (classroom) situations, pedometers have the capacity to gauge both children's activity and inactivity, intimating that pedometers are highly representative in normal free-living conditions.

3.3.3.2 Convergent Validity

As expected, subjects were much more active in the recreational environment than in the classroom, where they would be obliged to remain seated and predominantly sedentary. It is important to understand the nature of children's behavior in this setting; short bursts of high levels of activity combined with longer periods of low intensity activity and sedentary behavior (Sallo and Silla, 1997). As a result, it is understandable that the pedometer is less accurate in a classroom situation, children are mainly seated and little vertical movement takes place. This means that the pedometer does not record any g-force. With this in mind, the author suggests that pedometers are an accurate method of determining moderate to vigorous activity, but not lower intensity activity. It is this sort of moderate and vigorous activity that is most important to track and promote in children and adolescents.

Treuth and associates (2003) found pedometer determined activity to be only moderately correlated with accelerometers following a four day testing period. The pedometer used in this study required the subject to record their total step counts on a daily basis, and a lack of cooperation may explain the poorer association. The majority of pedometers now have the capacity to store daily step count over a number of days without any reliance on the subject to account for such limitations.

Overall, pedometers perform very favorably when compared with accelerometers. The comparative mechanical limitation of pedometers (measuring motion in one plane only) is a minor limitation, but the measurement of moderate and vigorous ambulatory motion is similar for both devices. Ramirez-Marrero (2005) recorded a stronger correlation between pedometers and accelerometers (r = 0.88) than between pedometers and the doubly-labeled water method (r = 0.67). This stands to reason as the doubly labeled water method is more suited to recording energy expenditure than step counts.

The comparison of pedometers with similar methods of physical activity measurement consistently shows that pedometers are just as effective as more widely validated methods like heart rate monitoring and accelerometry. Some concern has been voiced regarding pedometers' inability to measure sedentary behavior, and this is deemed an advantage of accelerometry. But the studies mentioned here provide encouraging evidence of pedometers being as effective as accelerometers in a sedentary, classroom setting.

3.3.3.3 Reliability

The accurate inter-unit agreement implied that pedometers are a reliable form of physical activity measurement and that the side of the body that the pedometer is worn is not relevant.

There were no significant differences between sites in these studies, suggesting that all were viable sites to validly establish activity levels in children. Even so, Graser (2007) recommended the right side of the waist as the optimum site for pedometer placement, solely because it allows the subject to read their step count. It seems that hip placement seems the most practical site for a pedometer. This ensures that ambulatory activity is recorded. Placement on the ankle or leg would cause a pedometer to record cycling and other similar movements. Although beneficial as a more accurate indication of physical activity, this would no longer solely constitute step counts. Widespread agreement and instruction on the proper placement of a pedometer remains relatively sparse, and more research is required to establish an accepted protocol across all studies. Such agreement would allow for confident comparison of results between studies.

Another important issue that needs to be considered when discussing reliability is sensitivity. This is the vertical threshold required to administer one step. Differences in sensitivity from one pedometer to the next may lead to variations in the accuracy of pedometers. For example, a CSA pedometer requires 0.3 g to register a step, while a YX200 pedometers requires 0.35 g, and this may explain the difference found between these two types of pedometers in a study by Tudor-Locke and associates (2002). Increased sensitivity means that slow steps can be recorded, but much more non-ambulatory movement like fidgeting and twisting is also recorded as a result.

The effect of body composition, and particularly obesity, on pedometer accuracy is another important reliability issue. A pedometer should ideally be placed in the vertical plane to ensure it registers displacement from ambulatory movement (Graser et al., 2007). This placement could potentially be affected by excess abdominal adiposity (Tudor-Locke et al., 2002). However, both Duncan (2007b) and Abel (2009) failed to find a significant difference in pedometer bias according to body composition. Both studies compared step counts according to waist circumference, while Duncan also employed BMI and percentage body fat. Duncan did note that pedometer bias was significantly affected by pedometer tilt-angle.

Although an important limitation of pedometer use, non-ambulatory movement like cycling and swimming is largely unreported in the literature. This is a significant issue that requires further research.

3.3.3.4 Feasibility

Pedometers are cheap and easy to use for both researchers and lay people. No limitations were mentioned in any of the studies citing an inability to operate them, or complaining about large costs incurred. With this in mind, pedometers are practical for use in large studies of children's activity.

Compliance is a particularly important feasibility issue related to the use of pedometers in large-scale field studies. The largest study reviewed here, Craig and associates (2010), highlighted a 97% compliance rate as one of the main achievements of the study. Elsewhere, compliance remains an under-reported but important issue. In the future, studies should include information on the rate of compliance and how this was achieved. This will allow other researchers to improve their methodology to ensure the highest possible levels of adherence in their pedometer studies and will also allow for easier comparison between studies.

Regarding reactivity, there is a concern that if someone is aware that their activity levels are being monitored, they will become more active. This may be particularly true for children and adolescents, given that they are inherently competitive. By comparing the effectiveness of sealed and unsealed pedometers, Ozdoba (2004) found no evidence of reactivity in either case. A significant difference occurred between days on one occasion, but given that this was probably due to the fact that it rained on this day, it was not deemed to represent reactivity.

Using only unsealed pedometers, both Rowe (2004) and Craig (2010) came to similar conclusions. The fact that there was no significant difference in mean step counts between day one and two suggests that children did not alter their behaviour because they were wearing pedometers. The debate about whether to seal pedometers centres on the concern that an unsealed pedometer might promote reactivity. Both of these studies suggest that neither sealed nor unsealed pedometers are affected by reactivity amongst children

As previously mentioned, the use of pedometers in a controlled clinical setting, such as on a treadmill, differs greatly from their use in a more realistic daily situation. With regard to validity, it is much easier to effectively gauge the accuracy and reliability of pedometers on a treadmill by comparing them to direct observation. This is not the case in a free living environment, where accurate direct observation is very difficult, if not unfeasible. Observing step counts on a treadmill simply involves the researcher counting consistently step by step. In a free living environment, the notion of 'one step' is much more ambiguous. In a classroom, a child may be seating but moving from side to side. Playing outside, they may hop, skip, jump, sidestep, run, walk and crawl all in a short period of time. Through direct observation, it becomes very difficult to discern whether or not any or all of these motions, which do constitute physical activity, are considered the equivalent of 'one step' by the researcher or by the pedometer.

Using a pedometer in a free living environment presents a number of other limitations. If a child is asked to walk on a treadmill for any amount of time, possible complications like defining outliers and accounting for missing data are of no concern. Usually in this type of study, subjects are only asked to walk for a few minutes, and the researcher puts on and takes off the pedometer immediately before and after testing. Given that a researcher is constantly present to monitor and instruct the subject, the pedometer should not be interfered with in any way.

In a free-living environment, children may be given a pedometer to wear for 7 days without any supervision. In this instance, children can lose, break or manipulate their pedometers. This results in missing data. If the pedometer is unsealed, children have the capacity to reset them, as observed by Ozdoba and associates (2004). This is of practical importance when planning a large-scale pedometer study, as sealing pedometers, although beneficial, is often very time-consuming and may be unfeasible.

Only one study (Rowe et al., 2004) covered the issue of outliers in any detail, proposing outliers of 1,000 to 30,000 for children. These limits were established primarily by establishing a reasonable range for step count scores based on prior testing experiences and hypothetical situations of extremely active and inactive children. The establishment of outliers for specific populations, both children and adults, is an important and under-reported issue that needs to be explored further.

3.3.4 Conclusion

A number of studies have investigated the inter and intra-unit reliability of pedometers, as well as their criterion and convergent validity, as established through comparison with direct observation, accelerometers and heart rate monitors. The current study reviewed these studies to establish the utility of pedometers as a determinant of physical activity amongst children and adolescents.

It is quite common for studies of this nature to investigate the merits of different methods by measuring physical activity levels as established by a subject walking on a treadmill. In doing so, some studies have proposed that pedometers are a valid method of physical activity measurement, particularly at moderate and fast speeds. However, children and adolescents do not do their physical activity on a treadmill. Field studies, with the validity of pedometers being assessed in free-living conditions, are a much more relevant indicator of activity levels. A number of such studies have been carried out and established that pedometers are reliable and valid measures of physical activity levels for children and adolescents.

Pedometers do have limitations, specifically with regard to the measurement of sedentary behavior and accounting for missing data. However, this is largely accounted for by the nature of children's behavior, short intense bursts of activity followed by longer periods of inactivity. Encouraging results also show high correlations between pedometers and both direct observation and accelerometers in low-intensity and sedentary environments. Positive levels of inter and intra-pedometer reliability promote the effectiveness of pedometers. Given they are relatively cheap and easy to use, pedometers can potentially be used in large-scale epidemiological studies and interventions, offering motivational and educational support. This review concludes that pedometers can effectively be utilized as a valid determinant of physical activity levels amongst children and adolescents.

CHAPTER 4 – ADIPOSITY IN YOUNG PEOPLE

4.1 INTRODUCTION

Anthropometry is defined as the measurement of the proportions of the human body (CDC, 1998). It is used to assess body composition and includes both external dimensions (height, weight, waist circumference) and internal dimensions (skinfold thickness, percentage body fat). In terms of epidemiological and public health research, body composition is primarily measured with a view to quantifying levels of adiposity (Goran, 1998). As one of the primary health risks associated with cardiovascular and metabolic diseases (Freedman et al., 1997, Hirschler et al., 2005, WHO, 1997), the ability to accurately measure adiposity levels is of great importance.

Body composition incorporates all of the different components that when added together, constitute a person's weight. These components are muscle, body fat, body water and bone. These components can be expressed as elements of body composition. They are lean mass, fat mass, body water and bone mass, respectively (MRC, 2011). Total body mass can also be expressed in terms of two elements, fat mass and fat-free mass.

Although the measurement of body composition is a growing discipline (Heymsfield et al., 1996), there remains a great deal of confusion and a lack of both understanding and consistency regarding the key terms and concepts associated with the discipline. The components of body composition are commonly interchanged with terms like adiposity, fatness, overweight and obesity. Adiposity refers to the presence of fat, or adipose tissue, in the body. It is sometimes less accurately described as 'fatness'.

Obesity is defined as having excessive body fat to the extent that it may impair health (WHO, 2011b). However, as with overweight, obesity can be determined in terms of many different anthropometrical measurements. While an established definition for obesity exists, the application of this definition into practice is not as clearly established. Obesity is not an exact or quantifiable measure in itself. It is interpreted from the measurement of other variables. Overweight and obesity are simply categories or statuses that are applied to other measures. For example, using internationally recognised guidelines (Cole et al., 2000), the cut-off point for obesity according to BMI is 21.7kg.m^{-2} for a 12yr old boy, 26.7kg.m^{-2} for a 12yr old girl, and 30kg.m^{-2} for adults, both male and female. Obesity is dependent on other variables, namely gender and age.

The two most common measures used to present and define the prevalence of overweight and obesity are percentage body fat (%bf) and body mass index (BMI). However, weight, waist circumference and skinfold thickness, along with many more methods, can also be employed as indices of overweight and obesity. To define overweight and obesity from an epidemiological point of view, it is necessary to define them in the context of specific measurement methods. Outlined below are some of the main methods of measurement.

4.2 METHODS OF MEASURING ADIPOSITY

4.2.1 Criterion methods

Measuring fat mass, as with measuring any of the compartments of body mass, is a very challenging task, and practically unfeasible to do so directly (Goran, 1998). As a result, various indirect methods have been developed to estimate adiposity, some more accurate than others, but all imperfect. A number of gold standard (criterion) methods are outlined here.

Computerized Tomography and Magnetic Resonance Imaging: These two similar imaging techniques are deemed to be the current gold standard methods for the measurement of fat mass (Hu, 2008). For computerised (or computed) tomography (CT), a three dimension image of the inside of the body is developed from a series of two-dimensional x-ray images (Herman, 2009). Magnetic resonance imaging (MRI) employs nuclear magnetic resonance to scan and create a detailed image of nuclei inside the body. It provides a very detailed contrast between different tissues within the body, making it easier to interpret than CT (Squire and Novelline, 1997). Both CT

(Tokunaga et al., 1983) and MRI (Seidell et al., 1990) have been established as accurate methods of measuring adiposity.

As CT imaging is the older, more established method, Seidell and associates (1990) compared it with MRI to investigate the validity of the latter. Bearing in mind the concerns regarding the use of CT on children, seven adult males had CT and MRI scans taken. A further seven adults (4 male, 3 female) had repeated scans taken using MRI, with a view to investigating its reproducibility. Intra-class correlation coefficients between MRI and CT indicated that they were significantly associated. This association held true for total body fat (r=0.985), visceral fat (r=0.791) and subcutaneous fat (r=0.996), thus validating MRI as an effective measurement tool. In terms of the reliability of MRI, there were acceptable coefficients of variation between the first and second test for total body fat (5.4%), as well as visceral (10.6%) and subcutaneous fat (10.1%). Although slightly more error occurred in terms of measuring visceral fat, the author concluded that MRI compared well with a criterion method as an acceptable method for predicting adiposity.

These scanning methods even have the capacity to differentiate between abdominal and subcutaneous adipose tissue. However, they are not suitable for use in large-scale epidemiological studies, particularly those involving children. Firstly, both methods can only be conducted in a clinical research setting. Equipment is extremely expensive and must be operated by highly trained individuals. The resultant image must also be interpreted by a highly trained individual. Also, CT scanning is not recommended for children due to the high amounts of ionising radiation used for this technique (2005).

Hydro-Densitometry: Also known as underwater weighing, this method involves measuring whole body density by determining body volume. Weight is measured outside of the water first, then once fully immersed. Using the knowledge that bone and muscle are more dense than water while fat is less dense, standard equations are applied to calculate full body density and then full body fat (Hu, 2008). As with the previous laboratory gold standard methods, densitometry is far from practical. Participants are probably required to travel to a laboratory to avail of the equipment and this can be logistically difficult when working with children. Investigators need to be trained to operate the equipment and to interpret the raw data. As a result, densitometry is an expensive and inconvenient option.

Dual Energy X-Ray Absorptiometry: Dual energy x-ray absorptiometry (DXA) is also regarded as a criterion method of adiposity measurement (Erselcan et al., 2000). Based on the principle that X-ray beams pass through different body tissues at different rates, a full body scan of the participant lying down is performed over 10-20minutes. DXA then uses these two x-ray scans to develop estimates of fat mass, as well as fat-free mass and bone density(Hu, 2008). Although similar to CT and MRI, DXA is more suitable in a clinical setting, thanks to the reduced cost of equipment and lessened burden on the participant (Sopher et al., 2004).

Sopher and associates (2004) investigated the validity of DXA for use in a clinical setting by comparing it to hydro-densitometry. Data was collected from 411 6-18yr olds and the two methods were compared using regression analysis. Although mean values for percentage body fat from the two methods differed slightly (DXA: 22.73% ± 11.23%, densitometry: 21.72% ± 9.42%), they were significantly associated with each other ($r^2 = 0.85$). According to the author, the results indicated that DXA was a newer, more practical and similarly accurate criterion method for establishing adiposity in children.

4.2.2 Body Mass Index

Body mass index (BMI) is a measure of weight-for-height, derived by dividing body mass (kg) by height (cm) squared. Although it does not provide a direct measure of %bf, it is commonly used to classify people as overweight, obese, healthy or underweight. It is quick and easy to measure, as well as being very inexpensive.

For adults, a BMI of 25 is widely employed as a cut-off point for overweight while a BMI of 30 is deemed obese (Must et al., 1991). These same guidelines cannot be applied as readily to children and adolescents, defining weight status for children is more complicated. This is primarily due to the fact that a child is constantly growing, and height and body mass both increase with time. As such, a child's BMI is constantly changing. For this reason, the Centre for Disease Control and Prevention (CDC) produced a chart showing the relationship between BMI and age which may be applied to children (Kuczmarski et al., 2000). Separate charts have been developed for boys and girls (see appendix I). In this instance, a child's BMI may be calculated normally and when used in conjunction with their age, the child's BMI percentile ranking can also be calculated. According to Himes and Dietz (1994) children and adolescents with a BMI above the 85th percentile are classed as at risk of overweight while those above the 95th percentile are deemed obese. Those below the 85th percentile are classed as normal.

When looking at studies that incorporate BMI as an indicator of obesity, it is important to note which particular recommended cut-off points were used for classification purposes. They may be based on CDC guidelines mentioned above, but they may also be based on the International Obesity Taskforce (IOTF) guidelines. Whereas the former are based on BMI percentiles, the IOTF guidelines, developed by Cole and associates (2000) were developed in correspondence with the 25/30 cut-off points for adults. Neither set of cut-off points, the CDC's nor the IOTF's, is widely accepted as being better than the other. Instead, both have been compared against each other, through correlation with other methods of measuring weight status, and determined that the better option is dependent on the cohort involved.

Kuczmarski's CDC guidelines (2000) were developed as part of the wider National Health and Nutrition Survey (NHANES), employing data gathered from 1963 to 1994, gathered exclusively from American children. The data was then transformed, using a Box-Cox transformation, to a near-normal distribution. When applied to percentile curves, the technique is known as the LMS technique (Cole, 1988), the equation of which is:

$$Centile = M\,(1 + LSZ)1/L$$

For this equation, M is the median, S is the standard deviation, L is the power in the Box-Cox transformation, and Z is the z-score that corresponds to the percentile. The resultant percentile curves could then be interpreted to establish gender and age-dependent 85th and 95th percentiles for children. Cole's IOTF guidelines were developed using the same LMS technique, although it was applied to a different sample. This was an amalgamation of 6 large studies (each n > 1000) based in Brazil, United Kingdom, China, Holland, Singapore and the United States of America. Using a different source for the development of percentiles, different thresholds for the 85th and 95th percentile were thus developed. It can be argued that for the most part, the IOTF guidelines are more suitable when classifying children as overweight or obese according to BMI. The threshold for overweight and obesity are more readily applicable to any sample of children, coming as they do from a more internationally representative (6 countries) sample themselves. The IOTF guidelines are slightly more sensitive to overweight and obese, as the mean BMI of the source sample was lower than the CDC's sample of American children.

As briefly mentioned in the equation for the LMS technique, BMI can be expressed as a standard score, commonly referred to as BMI z-score. The US CDC (Kuczmarski et al., 2000) and international IOTF (Cole et al., 2000) growth references used for the development of percentiles can also be used to convert BMI into BMI z-score. BMI z-score is particularly informative as it is adjusted for both gender and age (Cole et al., 2005), known correlates of BMI.

In a large-scale cross-sectional study in Japan, Komiya and associates (2008) gathered BMI data from over 100,000 schoolchildren. A unique overweight/obesity threshold for this cohort was compared with the IOTF guidelines (Cole et al., 2000). The study found that BMI percentile underestimates the prevalence of obesity while the thresholds for overweight and obesity developed by Cole and associates tend to slightly overestimate obesity. The study concluded that the precision of BMI-determined thresholds was extremely high, accurately diagnosing obesity in 93% of boys and girls.

Another similar study was carried out by Wickramasinghe and associates (2005), this time involving Australian children. Participants had BMI measurements taken, categorised according to IOTF guidelines and also presented as percentiles, while the deuterium dilution technique was used as a gold standard for validation. The study found that BMI percentile had a significant correlation with percentage body fat as determined by dilution technique. However, no such was found to exist between the IOTF cut-offs and dilution technique-derived percentage body fat. The author suggested that neither set of guidelines, nor those attained from BMI z-scores, were sensitive enough for detecting obesity. It was argued that the guidelines were too universal, as they did not account for ethnicity and as a result, ethnicity-dependent variations in fat distribution. These comments add strength to the argument that BMI determined overweight and obesity guidelines need to be ethnicity-specific.

Similarly, comparing skinfold thickness test-derived percentage body fat with the CDC and IOTF BMI weight status guidelines, Zimmermann and associates (2004) noted that while the guidelines were generally helpful, they needed to be further validated in specific populations. BMI and skinfold thickness measurements were taken from 2,431 Swiss children. Both sets of guidelines (CDC and IOTF) compared favourably with skinfold thickness-determined body fat when identifying those children deemed overweight but based on the results of the skinfold testing, the IOTF guidelines severely lacked sensitivity with increased adiposity, failing to detect almost 48% of girls and 62% of boys that had been classed obese. The study supported the validity of the CDC guidelines for BMI defined weight status but argued that the IOTF cut-offs need to be tested in more countries, across more ethnicities before they could be validated. These findings contradict previous concerns that the CDC guidelines, as opposed to the IOTF guidelines, are limited as they are not derived from a sample that is universally representative.

4.2.3 Waist Circumference

When establishing adiposity levels in young people, the nature and distribution of adipose tissue is often overlooked. There is a distinct difference between visceral and subcutaneous adiposity. The former refers to the intra-abdominal distribution of fat tissue, that is, in amongst the internal organs. It is also referred to as central fat. Subcutaneous or peripheral adiposity refers to the deposition of fat tissue just below the surface of the skin.

The distribution of fat plays an important role in determining the associated cardiovascular and metabolic risks (Freedman et al., 1997, Hirschler et al., 2005, Misra et al., 2005, Iwata et al., 2003). Centralised or upper body fat carries with it an increased risk of adverse metabolic or cardiovascular conditions (McCarthy et al., 2003). Given that obese children and adolescents tend to accumulate adipose tissue in the central and upper body as opposed to peripheral regions (Moreno et al., 1998), it is necessary to use an effective method of measuring central adiposity in children.

As with BMI, percentiles have been developed for waist circumference (WC). Specific percentiles have been developed for British children by McCarthy and associates (2001), employing the same LMS technique (Cole, 1988). The study provisionally recommended the use of the 85th and 95th percentile as indicators of overweight and obese. These percentiles and cut-off points are gender and age-specific.

Measuring waist circumference is a simple, cheap, reliable anthropometric test. As confirmed by a number of studies, it is also a reliable predictor of central obesity in children (Hubert et al., 2008, Freedman et al., 1997, McCarthy et al., 2003, McCarthy et al., 2001, Taylor et al., 2000, Hirschler et al., 2005, Cheng, 2005, Sarria et al., 2001, Iwata et al., 2003). Sarria and associates (2001) investigated the validity of waist circumference by comparing its accuracy as a predictor of obesity with underwater weighing, an established gold standard method. One hundred and seventy-five Spanish boys took part in the study and BMI was also recorded. Both BMI and WC compared favourably with percentage body fat in terms of both sensitivity and specificity as predictors of adiposity. While the author concluded that waist circumference was an adequate for clinical use and health promotion, they did warn that the results of this study could only be applied to white males. As with BMI, further validation is required across all ethnicities, ages and genders.

As highlighted by Sarria and associates (2001) and other studies, ethnicity is an important factor when measuring fat distribution in children (McCarthy et al., 2001, McCarthy, 2006, Hirschler et al., 2005, Misra et al., 2005). Misra and associates (2005) also argued that the accuracy of WC cut-off points is dependent on the ethnic group that they are applied to. The author stated that Asian children tend to have the smallest waist circumference while their Mexican counterparts have the largest. Looking solely at Chinese children, Iwata and associates (2003) found that international WC cut-offs for determining adiposity were irrelevant for that particular cohort. This study, along with Cheng (2005) states that although international WC cut-offs can not accurately be applied to Chinese children, they still provide better guidelines than international BMI cut-off points.

Cut-off points for waist circumference-determined adiposity should be ethnicity-sensitive. With regards specifically to fat distribution as opposed to fat mass, waist circumference is widely held as a more effective measurement tool than BMI (Hubert et al., 2008, McCarthy et al., 2003, McCarthy et al., 2001, Cheng, 2005, Iwata et al., 2003). Both Taylor and associates (2000) and Freedman and associates (1997) have developed WC cut-off guidelines. However, these guidelines are specific to the particular populations that they studied, white New Zealanders in the former and white and black Americans in the latter. It is not possible to apply these guidelines to study samples from other countries that may have different ethnic profiles.

Waist circumference is a reliable predictor of obesity related health risks, even amongst young people. These include cardiovascular disease and metabolic syndrome (Freedman et al., 1997, Hirschler et al., 2005, Misra et al., 2005). WC has also been found to correlate strongly with lipid and insulin concentrations (Sarni et al., 2006, Daniels et al., 1999, McCarthy, 2006, Hirschler et al., 2005). Hirschler measured waist circumference of 40 young boys (6-13yrs old), while also gathering information regarding glucose tolerance test, lipid profile, and insulin and proinsulin assays. Correlation coefficients were measured between variables and significant associations were established between WC and systolic BP ($r=0.64$), diastolic BP ($r=0.61$), high-density lipoprotein cholesterol level ($r=0.45$), triglyceride level ($r=0.28$) and proinsulin level ($r=0.59$). These findings clearly indicate that abdominal obesity, as determined by waist circumference, is a predictor of some of the components of metabolic syndrome and health risks associated with type II diabetes mellitus.

4.2.4 Bioelectrical Impedance Analysis

According to Cole and associates (2000), percentage body fat (%bf) is the ideal standard for measuring obesity. It represents fat mass as a percentage of total body mass. It can be attained in a number of different ways, the more popular of which have already been discussed, including underwater weighing, dual energy x-ray absorptiometry and full body image scanning test (Lazzer et al., 2005). Another method used to derive percentage body fat is bioelectrical impedance analysis (BIA).

BIA works on the basis of determining electrical impedance, the opposition to the flow of a small electrical current through the body. Using this value for impedance, an estimate of total body water can be calculated, and then fat-free mass and percentage body fat. Impedance is greater in fat tissue, as fat contains 10-20% water, in comparison with fat-free mass, which contains almost 70-75% water. BIA accuracy is thus affected by a person’s hydration levels; dehydration leading to a possible overestimation of adiposity levels. The validity of BIA as an accurate method for ascertaining %bf amongst children has been confirmed through a number of studies (Beertema et al., 2000, Cleary et al., 2008, Mast et al., 2002, Williams et al., 2007).

By measuring the levels of adiposity in a sample of 33 overweight and obese children, as measured by DXA, with %bf based on four different BIA equations, Cleary and associates (2008) aimed to investigate the validity of four different BIA equations. DXA was used as the criterion method of predicting adiposity against which the four BIA equations were compared. Two of the equations were developed by Deurenberg and associates (1991, 1989), one by Schaefer and associates (1998) and one by Houtkooper and associates (1992). Pearson correlation coefficients displayed a significant association between DXA and all four equations (r=0.834-0.856). However, the results indicated that for the particular cohort in question, young age white children, the equation developed by Schaefer provided the most accurate measure of %bf. So although previously validated in child populations, the three other equations, by Deurenberg and Houtkooper, were not accurate predictors of %bf amongst this specific cohort of overweight and obese white children. All of the equations, and Deurenberg's in particular, underestimated overweight and obesity. This was explained by the author as being a result of the fact that amongst children, there are differences in body geometry, body water distribution, and hydration of the lean mass compared to the fat mass. The author concluded that age, gender and ethnicity all need to be considered and adjusted for when predicting adiposity using BIA. This study highlights the importance of matching the cohort with the correct BIA formula.

Beertema and associates (2000) encountered similar findings when comparing four different equations to the isotope dilution method of measuring %bf. The study cohort consisted of 38 children from Holland, the majority of whom (n=32) suffered pathologic conditions. Only one of the four equations used, a population-derived equation previously validated in adults, provided similar results to the reference method. All four equations boasted high correlation coefficients when compared with the dilution method (r^2=0.91-0.93). However, when comparing means, only the equation developed by Van Kreel (1998) showed no significant difference from the dilution method. As all four equations had previously performed favorably when measuring adults, this study again shows the importance of matching the BIA equation to the cohort in question. The author noted that although DXA and underwater weighing are the most established reference methods for measuring %bf, they are also very expensive and time-consuming. In large-scale observational studies, where resources and costs are important factors, BIA and BMI measurement are much more common and popular methods for predicting adiposity as they are quick, easy and inexpensive to carry out. Beertema (2000) also highlighted that BIA is more accurate indicator of adiposity than the skinfold thickness test as the latter is prone to human error and fails to account for the difference between subcutaneous and internal fat.

Regardless of the advantages of BIA, the majority of associated studies highlight that BIA is only effective if coupled with the correct formula to ascertain %bf. In deriving an equation to estimate %bf based on BIA, Houtkooper and associates (1989) noted that although their BIA equation proved valid in their particular cohort, 10-14 yr old Caucasians, it needs to be cross-validated in other populations before it should be used on a more widespread basis and population. In contrast, Williams and associates (2007) argued that BIA equations are not as population-sensitive as some studies would suggest. By comparing four popular BIA equations, this study found that they were all highly correlated and that any one of the equations could be used in a large-scale study. However, this study did not compare BIA with a criterion method of adiposity measurement, instead employing the less reliable BMI.

4.2.5 Conclusion

There are many more methods for measuring adiposity in children than are discussed in this section. However, the methods included here are the most commonly employed in research relating to adiposity and young people. The most common methods for measuring and predicting adiposity in children are summarised in table 4.1.

Table 4.1 – Advantages and Disadvantages of Common Methods for Predicting Adiposity

	Advantages	Disadvantages
CT/MRI Scan	Highly accurate Differentiate between abdominal and subcutaneous fat	Massive cost of equipment Training required for operation and interpretation Impractical for large-scale studies
Densitometry	Highly accurate	Impractical for large-scale studies Training required for operation and interpretation Facilities required
DXA	Highly accurate	Expensive Time-consuming Cannot measure very obese
BMI (IOTF)	Cheap Easy to use and interpret Highly validated	Requires country-specific validation Not sensitive to fat distribution
BMI (CDC)	Cheap Easy to use and interpret Highly validated	Requires country-specific validation Only applicable to US population Not sensitive to fat distribution
WC	Cheap Easy to use and interpret Highly validated	Possible measurement error Lack of standardised overweigh/obesity cut-off points Ethnicity-specific cut-off points required
BIA	Relatively cheap Easy to use and interpret Highly validated	Lacks accuracy at extremities Lack of standardised formula for %bf

The prevalence of overweight and obesity amongst young people can vary significantly depending on the method of measurement employed. Variation can be increased further depending on the classification guidelines used, particularly for BIA. Gender, age and a fluctuating body shape mean that traditional guidelines, set out by BMI and by BIA equation-derived %bf, are not always applicable to large population samples.

Ethnicity also plays a role through its influence on body fat distribution. These factors ensure that predicting adiposity and ultimately classifying a child as either overweight or obese is a difficult task.

The accuracy of weight status as defined by BMI is significantly determined by the cut-off guidelines employed. Neither of the two most common methods, as set out by the CDC (using percentiles) and the IOTF (based on adult recommendations), have been cross-validated in a wide number of populations. As established correlates of BMI, age, ethnicity and gender will all influence the sensitivity of both these sets of guidelines. Both sets of guidelines need to be tailored to specific populations, although the IOTF guidelines are currently more applicable on a larger scale. The accuracy of bioelectrical impedance analysis is also dependent on demographic variables of the cohort involved. A number of different equations have been validated, again seemingly dependent in particular on the age and ethnicity of those involved. Percentage body fat results can vary widely depending on the equation used. Further research is required to validate BIA equations in specific populations, as compared with criterion methods.

The criterion or gold-standard methods, while accurate, are simply not practical for use in large scale cross-sectional studies involving children. The equipment is expensive, training is needed to operate it and interpret results, and the logistics associated with these methods are a major disadvantage. BMI, BIA and to a lesser extent WC, are all popular, cheap, efficient and validated methods of predicting adiposity and determining weight status in a clinical and research setting. It is important to acknowledge and adjust for the limitations associated with these methods, but these can be addressed and improved by adapting the methods and classification guidelines to the study sample involved.

4.3 ASSOCIATION BETWEEN STEP COUNT AND ADIPOSITY IN YOUNG PEOPLE

It is widely agreed that the prevalence of childhood obesity is increasing worldwide (CDC, 2000, DoH, 2008). This issue is compounded by the fact that childhood obesity tends to lead to adulthood obesity (Mossberg, 1989, Whitaker et al., 1997) (see section 2.2.1.1). At all ages, obesity is strongly linked to many cardiovascular and metabolic diseases (Freedman et al., 1997, Hirschler et al., 2005). Coupling individual medical concerns with potential economic concerns for society at large, stemming from increased stress on the health care system, the treatment and prevention of obesity is a very important issue (Davy et al., 2004, Duncan et al., 2006). The etiology of obesity is a multi-factorial problem, and many different mechanisms have been investigated to ascertain their role in terms of affecting obesity. This section aims to look specifically at how adiposity levels in children are affected by pedometer-determined physical activity by reviewing all available data on the topic. No such review, concentrating on pedometer-determined physical activity has been carried out previously.

4.3.1 Methods

The electronic databases PubMed, Web of Science, PsycINFO, CINAHL and SportDiscus were used to search for articles that satisfied the inclusion criteria. The specific inclusion criteria were:

4.3.1.1 Search Strategy

- Observational studies investigating the relationship between pedometer-determined physical activity and body composition
- Full text, English language publications
- Studies of males or females of any ethnicity between the age of 4-18 years

The exclusion criteria were:

- Case reports, editorials, comments, letters, abstracts and systematic & other reviews
- Randomized control trials or interventional studies
- Unpublished or non-English language publications
- Studies with adults or people with medical conditions as subjects

The specific search strategy consisted of three unique searches of similar terms, separated by the Boolean term OR:

#1: pedometer OR pedometers OR pedometry [title/abstract]

#2: body composition OR overweight OR obese OR obesity OR adiposity OR fatness [title/abstract]

#3: young OR youth OR children OR adolescents [title/abstract]

These three separate searches were then combined using the Boolean term AND to gather all possible papers and prevent duplication.

#4: #1 AND #2 AND #3 AND #4

Limitations were then applied to this search. The search was limited to articles from 1990 to the present date, given that the technology used in pedometers is constantly evolving and the current technology only began being reported in the mid 1990s. The search was also limited to English language articles.

#5: Limit (#4) – English, human, 1990-present

The titles and abstracts from all identified papers were assessed to determine their appropriateness for the research question. Results were compared across all five search engines and any duplicates removed. Full manuscripts of the articles deemed relevant and adhering to the inclusion and exclusion criteria were ordered. The reference lists of these papers were then cross-checked to identify any possible additional publications not previously found.

Reviewing the literature, specific data gathered from each of the articles included:

i. Study sample – age, gender, ethnicity, etc
ii. Pedometer methodology – model, number of days, treatment of data/missing data
iii. Obesity methodology – measurement taken, cut-offs employed
iv. Statistical methodology – tests employed to establish relationship

v. Results – strength of statistical tests

vi. Conclusion

4.3.1.2 Quality assessment criteria

The quality of each study included in the review was assessed using a combination of techniques. First, specific study quality criteria was assessed using a checklist originally devised by Liddle and associates (1997), since modified by the National Health and Medical Research Council (NHMRC, 1999). This method of quality assessment has previously been recommended by The Cochrane Collaborative Review Group on HIV Infection and AIDS in an editorial about the appraisal of experimental studies (CCR, 2004).

The quality of pedometry methods, based on a recent paper by Tudor-Locke and associates (2009), was also recorded. This covered issues such as brand of pedometer, reliability, reactivity, validity and treatment of data. It is the most comprehensive and authoritative such set of guidelines to date.

Bearing in mind the study details covered by both of the above checklists (quality criteria and pedometry methods) and acknowledging some other important study details, particularly study sample size, a subjective estimate was made with a view to classifying each study as being of either low or high quality.

It is important to note that this method of quality assessment, and the resultant classification of the studies herein, was developed with the specific aims of this review in mind. For example, while a study may be deemed as ‘low quality’ in this instance, such an assessment is relevant only to this specific review question, investigating the association between pedometer-determined physical activity and obesity in young people. So while the study may fit the inclusion criteria for this review but still be considered as low quality, it will more than likely be deemed as high quality in its original context.

4.3.2 Results

A flow chart of the number of papers included at each stage of the search strategy is shown below (table 4.2).

Table 4.2 – Search strategy for relevant articles

Search Stage	Medline	CINAHL	PsycINFO	SportDISCUS	Web of Science
#1	669	368	231	601	1002
#2	111492	17619	14028	11692	>100000
#3	624195	102779	285304	66756	>100000
#4	53	22	14	23	106
#5	52	22	14	23	104
Abstracts reviewed for relevance	15	4	2	4	23
Duplicates removed	12	1	1	0	4

In total, eighteen studies investigating the relationship between physical activity and adiposity in young people were identified (Al-Hazzaa, 2007, Al-Hazzaa and Al-Rasheedi, 2007, Beets et al., 2008, Belton et al., 2010, Davy et al., 2004, Downs et al., 2008, Duncan et al., 2006, Duncan et al., 2008a, Duncan et al., 2008b, Hands and Parker, 2008, Laurson et al., 2008b, Ng et al., 2006, Raustorp and Ludvigsson, 2007, Raustorp et al., 2006, Raustorp et al., 2004, Schofield et al., 2009, Vincent et al., 2003, Rowlands et al., 1999). Relevant data from all these studies is presented in the tables 4.3, 4.4 and 4.5 below.

Table 4.3 provides a brief overview of the key details of the eighteen studies covered by this review; participants, methodology, statistical analysis, results and conclusions. Study participants stem from a wide range of countries and ethnicities and cover children from ages 4 to 18. All bar two studies (Ng et al., 2006, Rowlands et al., 1999) had a sample size greater than 100. It is worth noting that all studies employed body mass index (BMI) as an indicator of overweight or obesity. Some studies also chose to employ other methods of obesity detection, namely waist circumference (WC), bioelectrical impedance analysis (BIA), waist-hip ratio (WHR) and skinfold thickness measurement. Cut-off guidelines were applied to establish adiposity status based on these different measures, participants being classified as either normal, overweight or obese. Statistical analysis, with a view to establishing the nature and strength of the relationship between activity and obesity, varied considerably across all 18 studies, as did the results and conclusions.

The key elements of the quality criteria assessment checklist are highlighted in table 4.4. This checklist provides information regarding the validity, reliability and rigorousness of the methodology employed across all studies. Specific details highlighted here include the percentage of possible participants that refused to take part along with the percentage of participants that failed to provide sufficient data for inclusion in the data analysis. These figures ranged from 7-37% and 3-25%, respectively. However, a number of studies failed to report these important figures.

Table 4.5 provides extended details of the methodology employed regarding the pedometer, a key measurement tool in these studies. All bar one of the studies used a recognized and accepted brand of pedometer for a minimum of 2 days. Other important methodological considerations presented in this table include the reporting of reactivity, reliability and the treatment of missing data. The majority of studies reported on the latter two but only 5 of the 18 reported as having addressed reactivity.

Bearing in mind the most important variables reported from these three tables, each study was subjectively classified as being of either high or low/unknown quality. Particular attention was paid to study sample size, statistical analysis, percentages not participating or not included in analysis.

Applying the quality assessment criteria, ten studies were subjectively classified as being of a high quality; Beets 2008, Belton 2010, Duncan, JS 2006, Duncan, MJ 2008, Duncan, JS 2008, Laurson 2008, Raustorp 2004, Raustorp 2006, Schofield 2009 and Vincent 2003. The remaining eight studies were deemed to be of a low or unknown quality; Al-Hazzaa 2007a, Al-Hazzaa 2007b, Davy 2004, Downs 2008, Hands 2008, Ng 2006, Raustorp 2007 and Rowlands 1999. The high quality studies are identifiable as being in italics in the tables below.

Eight studies reported a statistically significant association between activity and obesity. These are identifiable as the red studies in the tables below. Four of these studies reported r-values relating to the strength of the relationship between step counts and body composition variables (Hands and Parker, 2008, Laurson et al., 2008b, Vincent et al., 2003, Rowlands et al., 1999). The remaining ten studies found no significant association between variables (Al-Hazzaa, 2007, Beets et al., 2008, Belton et al., 2010, Davy et al., 2004, Downs et al., 2008, Duncan et al., 2008b, Ng et al., 2006, Raustorp and Ludvigsson, 2007, Raustorp et al., 2006, Raustorp et al., 2004).

Table 4.3 – Details of studies investigating the relationship between physical activity and body composition

Author, Year	Study Sample Characteristics	Outcomes	Risk Factors	Study Type	Obesity measurement	Statistical Analysis	Results	Conclusion
Al-Hazzaa 2007a	Saudi, 224, 109/115, 4-6	activity level	Obesity	cross-sectional	BMI, skinfold	2 factor ANOVA – age/gender vs. activity/adiposity	High obesity, low activity, No sig. difference between activity & adiposity	Not significant, despite the relationship tending towards the expected direction
Al-Hazzaa 2007b	Saudi, 296, 296/0, 8-12	activity level	Obesity	cross-sectional	BMI, skinfold	Pearsons – correlation between variables	High obesity. low activity, Sig. difference in step counts – normal vs. obese ($p=0.004$), Sig. differences in BMI/%BF – active vs. inactive ($p=0.000/0.009$)	Temporal relationship between activity and adiposity, although causality remains unclear
Beets 2008	*USA, 1067, 633/434, 6-12*	*activity level*	*Obesity*	*cross-sectional*	*BMI*	*Probability of correct decisions*	*Probability of correct decision = 0.47 (boys) and 0.46 (girls)*	*Limits of pedometer – cannot measure intensity, BMI cannot be used to determine (in)active*
Belton 2010	*Irish, 301, 148/153, 6-9*	*activity level*	*Obesity*	*cross-sectional*	*BMI*	*Logistic regression – activity vs. BMI/gender/age*	*No sig. relationship between activity & adiposity*	*Further study needed*
Davy 2004	USA, 205, 116/89, 11-12	activity level	Obesity	cross-sectional	BMI	Pearsons – correlation between variables	Low activity, high obesity, No sig. relationship between activity & adiposity	Diet remains a more important issue
Downs 2008	178, 9-11	activity level	Obesity	cross-sectional	BMI, WC	T-test – diff. in variables by adiposity group, Pearsons – correlation between variables, Logistic regression – odds ratio for adiposity	Weak relationship between activity & WC/BMI	Findings suggest activity is a necessary treatment for obesity
Duncan, JS 2006	*NZ, 1115, 536/579, 5-12*	*activity level*	*Obesity*	*cross-sectional*	*BMI, BIA, WC*	*One-way ANOVA/Bonferonni post hoc – diff. in activity according to adiposity group, Factorial repeated measures ANCOVA – association among activity and %BF group & covariates*	*Sig. difference between w/end activity and BMI group ($p<0.005$), Sig. difference between activity and %BF group ($p<0.05$)*	*%BF is most appropriate gauge of obesity*
Duncan, MJ 2008	*UK, 224, 114/110, 8-14*	*activity level*	*Obesity*	*cross-sectional*	*BMI, WHR, Skinfold*	*Pearsons – correlation between activity & body*	*No sig. correlation found*	

						adiposity		
Duncan, JS 2008	*NZ, 1229, 603/629, 5-11*	*activity level*	*Obesity*	*cross-sectional*	*BMI, BIA*	*Logistic regression – adiposity vs. Activity, ANCOVA - %BF for active vs. Inactive*	*Sig. relationship between adiposity and inactivity (odds ratio = 2.37)*	*Adiposity related to a number of lifestyle risk factors, including physical activity, Limitations of BMI*
Hands 2008	Aus, 1539, 787/752, 7-16	activity level	Obesity	cross-sectional	BMI, WC	Pearsons – correlation between variables	Sig. correlation between activity and WC (r=0.1, p<0.05)	Weak relationship but right direction, Obesity is multi-factorial
Laurson 2008	*USA, 709, 318/391, 8-10*	*activity level*	*obesity*	*cross-sectional*	*BMI*	*Logistic regression, Partial correlations – between activity and BMI*	*Sig. correlation between BMI & activity (r=-0.25 - -0.29)*	*Children meeting step count guidelines have better chance of having healthy BMI*
Ng 2006	Can, 82, 48/34, 9-11	activity level	Obesity	cross-sectional	BMI, WC, skinfold	ANOVA – difference in activity by body weight status group	No sig. difference between groups	Limitations of pedometer – no intensity / missing data
Raustorp 2004	*Swed, 871, 6-14*	*activity level*	*Obesity*	*cross-sectional*	*BMI*	*Pearsons – correlation between activity and BMI*	*Relationship was not significant but in expected (negative) direction*	*Must consider other benefits of activity – metabolic adaptations*
Raustorp 2006	*375, 176/199, 15-18*	*activity level*	*Obesity*	*cross-sectional*	*BMI, BIA*	*Pearsons – correlations between variables, Logistic regression – predict importance of variables*	*No sig. correlation*	*Relationship affected by many covariables*
Raustorp 2007	Swed, 504, 268/236, 7-9	activity level	Obesity	cross-sectional	BMI	T-test – difference in activity by BMI group	No sig. difference	Could improve methods - %BF>BMI, accels>peds
Rowlands 1999	Wales, 34, 17/17, 8-10	activity level	Obesity	cross-sectional	BMI, skinfold	Pearsons – correlation between activity and adiposity	Sig. correlation between activity and skinfold (r=-0.41, p=0.0017)	Causality unclear, Activity is important as it's modifiable
Schofield 2009	*Aus, 415, 0/415, 15-16*	*activity level*	*Obesity*	*cross-sectional*	*BMI*	*Logistic regression – activity vs. adiposity*	*Sig. difference between active/inactive and BMI (odds ratio = 4.7)*	
Vincent 2003	*USA/Swed/Aus,1954, 995/959, 6-12*	*activity level*	*Obesity*	*cross-sectional*	*BMI*	*Pearsons – correlation between activity and BMI*	*Sig. correlation between activity and BMI (r=-0.364 - -0.553)*	*Weak correlation – generalisations should be made with caution*

Studies in red reported a statistically significant association between pedometer-determined physical activity and obesity

Studies in italics are deemed to be high quality studies

Table 4.4 - Quality Assessment Checklist

Author, Year	Partic's well-defined?	% refused to participate?	Outcome measures standard, valid, reliable?	Risk factors & outcomes blind of each other?	All important risk factors included in the analysis?	% of individuals recruited not analysed?	Bias minimised?	Suggested further research?	Applicability of evidence to target population?	Importance to policy development?
Al-Hazzaa 2007a	y	n/a	Y	y	y	25%	y	n	y	Y
Al-Hazzaa 2007b	y	n/a	Y	y	y	n/a	y	n	n	Y
Beets 2008	*y*	*n/a*	*Y*	*y*	*y*	*n/a*	*y*	*step recommendation*	*y*	*Y*
Belton 2010	*y*	*28%*	*Y*	*y*	*y*	*n/a*	*y*	*n*	*n*	*Y*
Davy 2004	y	19%	n/a	y	y	15%	y	n	y	Y
Downs 2008	y	7%	Y	y	y	14%	y	more activity data	y	N
Duncan, JS 2006	*y*	*32%*	*Y*	*y*	*y*	*9%*	*y*	*longitudinal*	*y*	*Y*
Duncan, MJ 2008	*y*	*n/a*	*Y*	*y*	*y*	*10%*	*y*		*y*	*y*
Duncan, JS 2008	*y*	*n/a*	*Y*	*y*	*y*	*n/a*	*y*	*longitudinal*	*y*	*Y*
Hands 2008	y	n/a	Y	y	y	n/a	y	n	y	Y
Laurson 2008	*y*	*36%*	*Y*	*y*	*y*	*48%*	*y*	*cohort*	*y*	*n*
Ng 2006	y	6%	Y	y	y	22%	y	other factors/ outcomes	n	n
Raustorp 2004	*y*	*13%*	*Y*	*y*	*y*	*3%*	*y*	*n*	*y*	*y*
Raustorp 2006	*y*	*25%*	*Y*	*y*	*y*	*10%*	*y*	*longitudinal*	*y*	*y*
Raustorp 2007	y	17%	Y	y	y	n/a	y	activity intensity	n	n
Rowlands 1999	y	n/a	Y	y	y	9%	y	n	n	n
Schofield 2009	*y*	*9%*	*Y*	*y*	*y*	*12%*	*y*	*n*	*y*	*y*
Vincent 2003	*y*	*n/a*	*Y*	*y*	*y*	*n/a*	*y*	*longitudinal*	*y*	*y*

Studies in red reported a statistically significant association between pedometer-determined physical activity and obesity

Studies in italics are deemed to be high quality studies

Table 4.5 - Pedometry Methods

Author, Year	Yamax/NL brand?	Steps taken?	Validity reported?	Reliability reported?	Pedometer on hip?	2+ days?	Reactivity reported?	Account for missing data?	Outliers?
Al-Hazzaa 2007a	Y	y	Y	y	y	y	n	n	n
Al-Hazzaa 2007b	Y	y	Y	y	y	y	n	n	n
Beets 2008	*Y*	*y*	*y*	*y*	*y*	*y*	*n*	*y*	*y*
Belton 2010	*Y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*n*
Davy 2004	N	y	Y	n	y	y	n	n	n
Downs 2008	Y	y	Y	n	y	y	n	n	n
Duncan, JS 2006	*Y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
Duncan, MJ 2008	*Y*	*y*	*y*	*y*	*y*	*y*	*n*	*y*	*n*
Duncan, JS 2008	*Y*	*y*	*y*	*n*	*y*	*y*	*n*	*y*	*y*
Hands 2008	Y	y	Y	n	y	y	n	y	y
Laurson 2008	*Y*	*y*	*y*	*n*	*y*	*y*	*n*	*y*	*n*
Ng 2006	Y	y	Y	y	y	y	n	y	n
Raustorp 2004	*Y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*n*
Raustorp 2006	*Y*	*y*	*y*	*n*	*y*	*y*	*n*	*y*	*n*
Raustorp 2007	Y	y	Y	y	y	y	n	y	n
Rowlands 1999	Y	y	Y	n	n	y	n	n	n
Schofield 2009	*Y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*n*
Vincent 2003	*Y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*n*

Studies in red reported a statistically significant association between pedometer-determined physical activity and obesity

Studies in italics are deemed to be high quality studies

4.3.3 Discussion

This review aimed to investigate the nature of the association between pedometer-determined physical activity and obesity in young people by systematically reviewing all available literature on the subject. Eighteen studies were deemed to have addressed this question. Of these 18 studies, 8 studies concluded that there was a significant association between activity and obesity while the remaining ten studies concluded that the association was not significant. As expected, this is not a clear-cut issue, there was no universally accepted opinion on this subject before this review, and an initial glance at the results of these studies did not seem to challenge that position.

Of key importance to the lack of agreement is the fact that there was very little consistency across these studies regarding methodology or study design. As a result, the quality of the studies varied considerably. Some studies were considerably more thorough, regimented and better designed and reported than others. The implementation of a quality criteria checklist helped to grade and classify the studies. Ten studies were deemed to be of a high quality and eight were classed as low or unknown quality. This implies that while eight studies applied questionable methodologies to address the question at hand, ten studies addressed this topic in detail and thus warrant further investigation.

Table 4.6 - Classification of studies

	QUALITY (n)	
Association:	**HIGH (10)**	**LOW (8)**
Significant (8)	Duncan JS 06 & 08, Laurson 08, Schofield 09, Vincent 03 (5)	Al-Hazzaa 07b, Hands 08, Rowlands 99 (3)
Not significant (10)	Beets 08, Belton 10, Duncan MJ 08, Raustorp 06 & 07 (5)	Al-Hazzaa 07a, Davy 04, Downs 08, Ng 06, Raustorp 07 (5)

Looking specifically at those deemed to be high quality studies (see table 4.6), they are split evenly between studies that did find a significant association between activity and obesity and studies that did not. Some of these high quality studies are presented here in more detail.

4.3.3.1 High Quality Studies

According to Beets and associates (2008) obesity levels are rising in youth, with activity being highlighted as a prevalent factor for this trend and associated co-morbidities. International step count cut-offs have been established for children but the author claimed that these might not be sufficiently population-specific. In this study, Beets aimed to investigate how applicable the current cut-offs were amongst US boys and girls. Four days of pedometer activity data was recorded. Compliance levels, outliers and missing data were all accounted for. BMI was calculated for 633 children and the probability of correct decisions, sensitivity and specificity were all gauged for weight classification according to activity status. In effect, the association between step counts and BMI-determined weight status was being investigated.

Unfortunately, the author failed to report on percentage refusing to participate and percentage not analysed. Although this is probably because this is a secondary analysis of the data, it does slightly compromise the quality of an otherwise well conducted and reported study. The overall probability of correct decisions, covering both specificity and sensitivity, for boys and girls was 0.47 and 0.46, respectively. Sensitivity (inactive)/specificity (active) were 0.77/0.34 for girls and 0.83/0.28 for boys. The odds ratio of being correctly identified as overweight or obese based on step counts was 1.8 and 1.94 for girls and boys, respectively.

These findings implied that the current cut-offs do not seem to suit a US population, as they lack the ability to identify unhealthy and overweight children. Sensitivity and specificity, the measure of correctly identifying actual positives and negatives, respectively, were both quite low for boys and girls alike. Beets concluded that current activity recommendations should be applied with caution as they fail to distinguish weight classification in youth, citing limitations of the methodology, pedometers and BMI, as a possible reason for the study’s findings. However, the author failed to account for a possible flaw in the theory applied to the development of the step-count recommendations. These are BMI-determined cut-offs, and thus rely on the assumption that there is a strong association between BMI and step counts amongst children. Judging by the findings of this study, this did not seem to be the case. A highly active child is not necessarily going to have a healthy BMI and it is incorrect to assume that an inactive child is automatically going to be overweight or obese. The findings of this large-scale study failed to find any such association between pedometer-determined physical activity and obesity, possibly due to the absence of an association between activity and obesity.

Similarly, Laurson and associates (2008b) aimed to investigate the accuracy of current step count cut-points as a predictor of obesity amongst young people. This study looked more favourably at current step count recommendations, discovering that inactive boys and girls were 2.74 and 2.37 times more likely to be overweight than of a healthy weight. When coupled with screen time, these figures rose to 4.5 and 3, respectively. Those who did meet the guidelines were less likely to be overweight. These findings, contradicting those of Beets, may be explained by the fact that only 52% of participants provided data for analysis in the latter study. Although the study failed to provide detail on the matter, this high drop-out rate could possibly be attributed to overweight and/or inactive youths, thus skewing the results.

In the first of three similar studies carried out by Raustorp and associates (2004), the author pointed to the links between rising obesity levels and health problems, hypothesising that this was related to physical inactivity. The study aimed to look at the exact nature of the relationship between obesity and physical activity in a sample of Swedish youths. Four days of pedometer data were taken from 871 children, with the study design accounting for both missing data and reactivity to pedometers. Results showed that step counts were high throughout the group, and less than 20% of participants were overweight or obese. However, applying Pearson's correlation coefficient, no significant correlations were found between activity and obesity, with r-values ranging from 0.235 to -0.242 depending on age and gender.

The author argued that if activity is related to obesity, it seems paradoxical that while activity is important in preventing weight gain, activity alone does not seem to result in weight reduction. One possible reason for the poor correlation may have been that obesity levels were surprisingly low in this instance, leading to low numbers of youths being classified as overweight/obese. Thus, comparison between groups based on weight status may have been difficult, as activity levels compared here may not have been representative of the wider overweight/obese population. Alternatively, one could reasonably conclude that this was a well planned, executed and reported study. Thus, the findings should add a credible opinion to the argument that there is no discernible association between activity and obesity.

However, Raustorp did raise an important point when concluding that activity is only one factor in the complex issue of weight management. There are other, metabolic benefits to be had from physical activity, so regardless of the weight-related benefits, increased physical activity must be promoted amongst children. An active lifestyle will lead to long-term health benefits, regardless of the strength of the association between activity and obesity.

In another study conducted by Raustorp and associates (2007), the author aimed to look at pedometer-determined activity and obesity levels over a 6 year period. Again, there were no significant differences in the step counts of normal and overweight children. Similar to the findings of the study by Beets and associates (2008), large discrepancy between overweight and step recommendations implied that current step count recommendations may need to be reconsidered before being applied to a group of Swedish children. This highlights potential flaws in the use of BMI-defined step count recommendations, further questioning the strength of the correlation between activity and obesity.

Duncan and associates (2006) also introduced their study by stating that the current obesity epidemic has many related health risks, leading to the widespread promotion of physical activity. However, the importance of activity in terms of obesity remains under-reported. This study hypothesised that the weak evidence of a correlation between activity and obesity may be in part due to the use of BMI to define the latter. The author argued that waist circumference and particularly bioelectrical impedance analysis-determined percentage body fat were potentially more reliable methods for measuring adiposity, as this study aimed to establish.

In total, 1,115 children had 5 days of pedometer data taken. Reactivity, reliability and missing data were all reported, highlighting that the study was very thorough in terms of pedometry methods. Participants were also classified according to ethnicity and SES. BMI, WC and %bf were all measured and standard cut-offs were applied. One-way ANOVA/Bonferonni post-hoc tests were used to establish differences in activity according to adiposity group, ethnicity and SES. Associations between activity and all subgroups were also assessed using factorial repeated-measures ANCOVA. Sex, ethnicity, %bf category and day were entered into a 2x3x2x2 factorial repeated measure ANCOVA, age and SES the covariates.

Statistical differences in adiposity levels according to both gender and ethnicity were observed, as determined by all three methods of measurement. Activity differences were also observed according to ethnicity. Significant difference in steps count totals were reported according to BMI, WC and BIA-determined weight categories. The most significant correlation was found according to high %bf (9.5%) and normal (90.5%). Analysis of the between-subject variance revealed significant associations between overall mean step count and both age and SES. Significant differences between boys and girls, among ethnicities, and between %BF groups were also detected. The latter finding, in addition to the non-significance of the interaction between day and %BF, suggested that a high level of %bf (>90^{th} percentile) was associated with a significantly lower number of daily steps on both weekdays and weekends.

It is important to note that this study (Duncan et al., 2006) was subjectively established as the highest quality of all studies, given how it thoroughly addressed all pedometry method and quality assessment criteria. The statistical analysis employed was also particularly in-depth, including one of the few occasions that multivariate analysis (in the form of repeated-measured ANCOVA) was employed in a study. As expected, gender was the most strongly associated correlate of step count-determined physical activity. The association between BMI and step counts was rather tenuous, justified by the author explaining that BMI is limited in its ability to predict overweight and obesity in youth. Waist circumference, more adept at establishing central fat distribution, provided a significant correlation with activity. WC may be a more sensitive tool for predicting adiposity in this multi-ethnic population sample. Percentage body fat, as established by BIA, is more accurate and more reliable than skinfold thickness testing, having been validated against more accurate and expensive methods of adiposity measurement. Percentage body fat was associated with step count activity, regardless of sex and ethnicity. The author concluded that activity and adiposity were associated, the link most evidently expressed by through BIA-determined adiposity levels. This study conducted by Duncan (2006) highlighted concerns regarding the accuracy of BMI, particularly amongst children. According to the author, both WC and BIA are better indicators of obesity and as such, will lead to a stronger association with physical activity if such an association exists. With this in mind, the study concluded that step count recommendations should be made using %BF, as opposed to the BMI step count recommendations derived by Tudor-Locke (2004)

In a second New Zealand-based study by Duncan and associates (2008a), inactive children were more than twice as likely to be overweight as their active counterparts (odds ratio=2.37). Another high quality study, applying BIA as opposed to BMI to predict obesity, the author again concluded that obesity was associated with inactivity, noting also that the association became increasing evident when inactivity was coupled with other risk factors such as diet and sleeping pattern.

Schofield and associates (2009) also aimed to investigate the association between activity and obesity, doing so by investigating the daily step counts and prevalence of negative health risk factors in a sample of 415 girls. BMI and 4 days activity were measured, amongst other health risks and indicators of obesity. Blood pressure was measured and fitness was gauged using a heart rate-derived V02 formula. Six specific factors were selected as CHD risk factors; activity (<10,000), overweight and obesity ($85^{th}/95^{th}$ percentile BMI), history of heart disease, fitness (<37ml/(kg.min)) and smoking. The relationships between activity and all of the risk factors were investigated using logistic regression analysis, with activity as the dependant variable. The breadth of variables measured and incorporated into analysis ensured that this was another high quality study.

Fifty-nine percent of the sample were classed as inactive (<10,000 steps). Step count cut-off points were associated with fitness (OR=2.15), but not with any other health risk factors, when categorised as 'active' (>10,000 steps) and 'inactive'. However, BMI was associated with activity when participants were given activity classifications based on step count quartiles (obese, odd ratio=4.7). Inactive girls were more likely to have three risk factors, including being overweight/obese, too (odds ratio=0.0).

The study employed two different methods for classifying participants as either active or inactive. The first method was a 10,000 step cut-off that was too high and thus, did not lead to any noticeable difference between groups. However, the second method, comparing the 4th (11,179 steps) and 1st quartiles (7,409 steps) did lead to differences in BMI between groups. This seems intuitive given that the 1st and 4th quartiles represent the step count values at opposite ends of the range. It was calculated that the risk factors chosen accounted for up to 75% of the risk of CHD, with activity and fitness accounting for 30% alone. This study showed that single risk factors are usually poorly associated with activity, they need to be combined to have a significant impact on the outcome, such as the combination of obesity and fitness. Clustering risk factors compensates for fluctuation observations, establishing stronger associations. This observation, that adiposity is a multi-factorial issue, affected by activity amongst a lot of other variables, was a consistently derived conclusion or opinion across all of these studies.

Another high quality study by Vincent and associates (2003) aimed to investigate the nature of the association by taking activity and BMI measurements from 1,954 children. The study sample consisted of children from USA, Sweden and Australia, a convenience sample gathered from all three regions. All limitations concerning pedometers, missing data, reactivity and reliability, were accounted for in this study. The study failed to report response rates. Pearson's correlation coefficient was calculated to establish the presence of any associations between step counts and adiposity. Significant associations were observed for 5 of the 40 specific sub-cohorts but not for the group as a whole. These significant correlations included American 11 and 12yr old boys (r=-0.389/-0.553), American 9yr old girls (r=-0.364) and 8yr girls from America and Australia (r=-0.276/-0.331).

The high quality of this study was derived from its wide scope, including a broad range of young people, of differing gender, age and nationality. Coupled with a very thorough methodological process, it provided high quality data regarding the nature of the association between physical activity and BMI-determined adiposity. Significant associations were observed, although there was no specific pattern derived from the five instances an association was observed. The author hypothesised that students from the USA may have been from a lower SES, acting as a potential confounding variable. However, this was not recorded. Seeing as such a wide number of potentially significant correlations were calculated (40), this may have increased the likelihood of observing statistically significant correlations in some instances. Indicative of the overall review, significant association may be established by chance if enough correlations (of different cohorts) are tested for significance.

The lack of consistency across countries may be explained by the fact that children in each of three cohorts may have experienced completed different socio-demographic and environmental variables. This was noted by the author, who concluded that generalisations should be made with caution even though a relationship between activity and adiposity seems intuitive. The cross-sectional nature of the study meant that conclusions regarding causality could not be made. BMI was also cited as a possible limitation, as a screening tool as opposed to as an accurate indicator of overweight/obesity.

Belton and associates (2010) pointed to the health benefits of an active lifestyle, particularly one that begins in youth. Previous studies reported a significant association between inactivity and obesity and the study by Belton aimed to further investigate the association in children aged 6-9yrs in Ireland. The study failed to find a significant association between activity and obesity. This could potentially be explained by the fact that activity levels were encouragingly high, 65% of the cohort reaching current step count recommendations. This observation can is justified by the young age profile of the study cohort, as it has been established that children tend to become less active as they get older (Brodersen et al., 2007, Telama, 2009).

As indicated by these high quality studies, there is no conclusive answer or universally accepted opinion as at to the nature of the association between pedometer-determined physical activity and obesity. Certain issues, alluded to in these studies, and echoed in other lower quality studies consistently recur and may help explain the association between activity and obesity. The etiology of obesity is multi-factorial. Although a direct association between activity and obesity does seem intuitive, it is also affected by a multitude of confounding variables.

4.3.3.2 Etiology of Childhood Obesity

Despite a great deal of research conducted and published on the topic, the exact etiology of childhood obesity remains unclear (Duncan et al., 2008b, Rowlands et al., 1999). It is commonly accepted that an increase in body weight stems for an energy imbalance, when energy consumption is greater than energy expenditure (Delaney, 1998). Energy expenditure and consumption are influenced by a wide variety of factors. As highlighted by Duncan and associates (2008b), these factors are either non-modifiable demographic ones or modifiable behavioural factors. Whereas the former refer to hereditary factors such as parental obesity, the latter covers factors such as diet and level of physical activity.

Applying the basic principle of the energy balance equation to the current childhood obesity epidemic, the increase in the prevalence of childhood obesity worldwide in recent years has not been accompanied by a significant increase in energy consumption (Prentice and Jebb, 1995, Troiano et al., 2000). Raustorp and associates (2007) suggest that this indicates that a reduction in energy expenditure is a more significant factor. It is implied that rather than children consuming more energy in the form of a less healthy diet, energy expenditure and in particular, a reduction in physical activity levels plays a more important role in the development of childhood overweight and obesity. With this in mind, it seems intuitive to assume that physical activity is negatively associated with adiposity levels, even though the evidence does not necessarily support this theory.

Coupling this knowledge with the fact that physical activity is a relatively easily modified, behavioural factor, physical activity/exercise seems to be an obvious factor to target for obesity prevention and treatment. Physical activity is widely promoted and employed in interventions to stem obesity and related disease. However, the exact nature of the relationship between physical activity and obesity remains unclear. All of the studies presented here aimed to confirm this assumption and accurately define the relationship between pedometer-determined physical activity and obesity.

Many of studies included in this review concede from the outset that obesity is a multi-factorial issue (Duncan et al., 2008b, Laurson et al., 2008b, Raustorp et al., 2006). A number of studies conclude that regardless of the strength of the role played by pedometer-determined physical activity, adiposity is a complex issue related to many demographic, environmental and lifestyle variables (Duncan et al., 2008a, Raustorp et al., 2006). Demographic variables include ethnicity, socio-economic status and parental weight status, factors that cannot be modified. Lifestyle-related variables can be modified and include activity levels, diet, sleeping patterns and amount of time spent sedentary (TV/video games). The multi-factorial nature of adiposity is exemplified by the findings of a number of studies. Both Laurson (2008b) and Scholfield (2009) accounted for a number of adiposity-related risk factors in establishing a significant association between activity and obesity. As part of their study Davy and associates (2004) also recorded dietary habits, the author noting that diet is a more important factor to be modified when trying to reduce adiposity levels in youth.

4.3.3.3 Methodological Issues

As evidenced in the studies reviewed here, there is no universally accepted protocol regarding study design and methodology when investigating the relationship between activity and adiposity. All studies employed varying methodologies, making direct comparisons difficult. The application of quality assessment criteria, in the form of both the checklist and pedometry methods, allows for the subjective classification of studies as high, low or unknown quality. As a result, high quality studies, studies that employ a sound study design and methodology, can be investigated in more detail and low quality studies can be assessed as such.

In accordance with the inclusion criteria, subjects varied in age from 4 to 18 years of age and the majority of studies included both boys and girls. All studies used pedometers to establish physical activity, displaying results as step counts. However, the utility of pedometers is questioned in many of these studies. Although widely accepted as a valid tool for the measurement of physical activity, particularly in large-scale studies, pedometers do have some inherent limitations. Beets (2008), Ng (2006) and Raustorp (2007) all cited pedometers' inability to report activity intensity as a possible reason for the lack of a significant association between activity and adiposity. Unlike more expensive motion sensor monitors like accelerometers, pedometers record only step counts, offering no information regarding activity intensity. This also means that important factors such as inactivity and sedentary behaviour go unrecorded; these are potential lifestyle risk factors themselves, and may have as important as role to play in the etiology of obesity as does physical activity. In spite of these limitations, pedometers are deemed to be valid instruments in large-scale observational studies. The first attempt at establishing a widely agreed protocol for their use was only recently presented by Tudor-Locke and associates (2009). It is hoped that future studies will follow that report's recommendations, leading to better reported pedometry studies.

Step count cut-offs were employed to differentiate between those participants deemed 'active' and 'inactive'. However, there remains no widely accepted step count cut-offs for children (see section 2.4). The most commonly employed guidelines are those suggested by Tudor-Locke and associates (2004) (boys = 15,000 steps/day, girls = 12,000 steps/day) and Duncan and associates (2007a) (boys = 16,000 steps/day, girls = 13,000 steps/day). Laurson and associates (2008a) applied a third, unrecognised cut-offs of 13,000/11,000 steps for boys and girls, respectively. The validity of these step count cut-offs are questioned by both Beets (2008) and Laurson (2008b), both authors noting that the cut-offs are inaccurate predictors of weight status. Again, this may be explained by an inherent flaw in the use of BMI-defined cut-offs points, given the association between the two variables is not fully understood. Further studies need to confirm the nature and strength of the association between BMI or BIA-determined obesity and step counts.

BMI measurements were taken in all eighteen studies. Waist circumference, bioelectrical impedance and skinfold thickness testing were also conducted in selected studies. Previously established cut-offs for each of these variables were then applied. However, much like step count recommendations, these cut-offs are not universally accepted and as a result, they varied between studies. In both studies by Duncan and associates (2006, 2008a), the author questioned the validity of BMI as an indicator of adiposity in children. Given that the study sample was drawn from New Zealand, consisting of white European, Polynesian and Asian children, BMI was potentially not particularly sensitive to the ethnically diverse population, compared with BIA, WC or skinfold thickness (Duncan et al., 2006). This is supported by results showing that a high BIA-determined %BF is a better indicator of low activity than BMI. The author suggested that a significant association does exist between activity and obesity, and given that BIA is a more accurate indicator of obesity than BMI, the correlation is more easily observed for the former measurement.

Pedometer data was collected over the course of between 3 and 8 days. On average, studies that reported a significant relationship had pedometer data collected over 5.5 days, compared with 3.8 days for studies reporting no significant relationship. It is important to note that the mean sample size for studies that made significant findings was 786, compared with 504 for studies that failed to uncover any significant findings. Looking solely at studies deemed to be of a high quality, five studies established a significant correlation and five failed to do so. Interestingly, the average sample for these two subgroups was 1,084 and 568, respectively. A smaller sample size can lead to increased difficulty in establishing significant findings, as the power of the study may have been too low. The reduced sample sizes could potentially have affected the ability of the latter studies to observe statistically significant associations.

Statistical analysis of the presence of a significant association varied greatly, no two studies employing the same statistical tests. Pearson's correlation coefficient was measured in some papers, as was ANOVA. In an effort to account for confounding factors, multivariate analysis, linear regression and ANCOVA, was employed in some instances. Given the majority of studies suggest that obesity is affected by a number of factors, multivariate analysis, accounting for at least one confounding variable, seems essential in studies of this nature.

The fact that this relationship was reported in both directions, the hypothesis that a healthy active lifestyle can predict a healthy weight and vice versa, highlights a limitation of all of these studies. Given their cross-sectional design, none of the studies came to any conclusions regarding causality (Al-Hazzaa and Al-Rasheedi, 2007, Rowlands et al., 1999). The exact mechanism of the relationship between activity and obesity remains unclear; does inactivity lead to or stem from obesity? Also, quality assessment highlighted a number of key study details that have not been reported. Reactivity, a possible limitation, was not mentioned in thirteen studies while there was no mention of outliers in fourteen studies. Also, almost half of the studies failed to report the completion/compliance rates in their study.

An inherent, potential limitation amongst the studies covered in this review is the choice of measurement tool and resultant output measure used to represent physical activity. For all studies critically evaluated here, physical activity was presented as pedometer-determined step counts. As discussed in detail in sections 3.2 and 3.3, pedometers can provide a valid, reliable and accurate measurement of physical activity. Like all methods of measurement, they have both advantages and disadvantages, but are particularly suitable for use amongst children in large-scale studies conducted in a free-living environment. However, it is important to consider whether pedometers provide the most suitable measurement of physical activity for the observation of an association with adiposity. Pedometers are limited in terms of the dimensions of physical activity they can record, particularly given their inability to record physical activity intensity. Given the unique nature of children's physical activity, short burst of high intensity activity followed by sustained periods of sedentary behaviour, it could be hypothesised that pedometers lack the sensitivity to measure the type of activity beneficial to the prevention of obesity. Measurement tools like direct observation and accelerometers can record children's physical activity intensity. Would the nature of the association between physical activity and adiposity be different if these other validated methods of measurement were used instead?

A cursory look at the association between adiposity and accelerometer-determined physical activity suggests a lack of agreement similar to that encountered using pedometers. In a longitudinal study conducted by Metcalf and associates (2008), BMI and accelerometer data was gathered four times in one year to investigate the relationship between government-recommended physical activity levels and obesity. No significant associations were observed for boys or girls. In a more recent longitudinal study, the association between DXA-determined fat mass and accelerometer-determined physical activity was investigated in 577 children at ages 5, 8 and 11 (Kwon et al., 2011). Significant associations were observed for boys at age 11 and for girls at ages 8 and 11. The study concluded that obesity-related health benefits of activity may only be observed in older children. A recent systematic review conducted by Wilks and associates (2011) investigated the association between accelerometer-determined physical activity and obesity for both children and adults. Twenty-one studies, seven comprising adults, were included in the review. Overall, no agreement regarding the nature of the association could be deduced from this review. Only twelve of the studies reported a significant negative association between physical activity and obesity, the remaining nine failed to do so.

Similarly, when direct observation is employed in a study, the nature of the relationship between activity and adiposity differs from study to study. In a study by Fulton and associates (2009), direct observation was employed to determine moderate-to-vigorous physical activity (MVPA) among 472 10-14yr old children. Bioelectrical impedance analysis-derived fat mass and BMI were both negatively association with MVPA for boys and girls. Trost and associates (2003) conducted a similar study amongst 3-5yr old children, also employing direct observation to determine physical activity levels. The study reported significant negative associations for boys but not for girls. This cursory review of studies employing both direct observation and accelerometer-determined physical activity suggests that while they can record physical activity intensity, neither method can provide a clearer insight into the nature of the association between physical activity and adiposity.

4.3.4 Conclusion

In addressing the relationship between physical activity and obesity, many of the studies reviewed reported very high levels of obesity in their samples (Al-Hazzaa, 2007, Al-Hazzaa and Al-Rasheedi, 2007, Beets et al., 2008, Duncan et al., 2006, Ng et al., 2006, Raustorp et al., 2004). While the exact nature of the relationship between physical activity and adiposity remains unclear, the majority of these studies concede that physical activity, while not the only factor at play, is one of a number of factors that can affect adiposity levels (Al-Hazzaa, 2007, Al-Hazzaa and Al-Rasheedi, 2007, Downs et al., 2008, Duncan et al., 2008b, Hands and Parker, 2008, Laurson et al., 2008b, Ng et al., 2006, Rowlands et al., 1999, Schofield et al., 2009). With this in mind, the promotion of physical activity has become a popular tool for the prevention and treatment of obesity and related diseases (Belton et al., 2010, Schofield et al., 2009). It should continue to be promoted, and can be affectively implemented through the promotion of step count guidelines for boys and girls.

The lack of agreement between these studies ensures that it is not possible to conclusively define the nature of the association between step counts and adiposity in young people. Separating studies according to their quality also failed to suggest the development of a trend either for or against the presence of a significant correlation. Although no confident conclusions can be made, a number of important issues arise from reviewing these studies. An improved and universally accepted study protocol is warranted to better investigate the nature of the association between pedometer-determined step counts and adiposity. Positive steps have been made in this regard by both Tudor-Locke (2009) and Duncan (2006), providing the framework for future studies. Improved statistical analysis must account for other confounding factors. Regardless, the study design may be inherently flawed given the multi-factorial nature of the etiology of obesity. It is not possible to definitely state that activity plays a positive roll regarding adiposity but there is some evidence, particularly in the higher quality studies, that activity is one of a number of important factors related to overweight and obesity. Further research is warranted to investigate this relationship, while controlling for significant confounding variables. Comparisons of the association according to gender, age and ethnicity may help to provide a clearer insight into this issue. Even so, physical activity has many other health benefits and should continue to be promoted towards leading a healthier life.

CHAPTER 5 – PRIMARY RESEARCH PROJECT

Investigating Physical Activity in Tower Hamlets Youths: The Role of Ethnicity and Socioeconomic Status

Tower Hamlets is one of the 32 boroughs in Greater London. It is also one of the twelve boroughs that comprise Inner London, and is based in the East End of the city. The borough, as an administrative area, was formed in 1965 through the amalgamation of the former Inner London boroughs of Bethnal Green, Poplar and Stepney (2010). It is bordered by the financial end of the City of London to the east, the Thames River to the south, the borough of Hackney to the north and Newham to the west. The borough is also home to Canary Wharf, the European headquarters of many large financial organisations. Tower Hamlets is notable in terms of the uniquely diverse ethnic and socioeconomic profile of its inhabitants.

5.1 POPULATION DEMOGRAPHICS

5.1.1 Ethnic Profile of Tower Hamlets

The area has a long history of foreign immigration. In the 17th century, it was the primary destination for a great deal of Huguenot refugees, followed later by Irish immigrants and then Ashkenazi Jews (2010). It was only in the 20th century that Tower Hamlets became a popular point of arrival for vast numbers of Bangladeshi immigrants (Aftab et al., 2005), the results of which are evident in today's population.

The borough's population fell from 490,000 prior to World War II, to approximately 140,000 in 1981. The current population of Tower Hamlets is estimated at almost 235,000 (ONS, 2011). The ethnic profile of the borough is presented in the table 5.1.

Table 5.1 – Tower Hamlet Population Estimates (%) by Ethnic Group

		Tower Hamlets	London	England
TOTAL:		234,800	7,753,600	51,809,700
WHITE:	Combined	57.1	69.7	87.5
	British	47.7	59.5	82.8
	Irish	1.3	2.2	1.1
	Other White	8.1	8	3.6
MIXED:	Combined	2.8	3.5	1.9
	White and Black Caribbean	0.8	1	0.6
	White and Black African	0.4	0.5	0.2
	White and Asian	0.9	1	0.6
	Other Mixed	0.7	1	0.5
ASIAN/ASIAN BRITISH:	Combined	30.6	13.2	6
	Indian	3.5	6.2	2.7
	Pakistani	1.6	2.8	1.9
	Bangladeshi	20.6	2.2	0.7
	Other Asian	4.9	2	0.7
BLACK/BLACK BRITISH:	Combined	6.3	10.1	2.9
	Caribbean	2.2	4	1.2
	African	3.6	5.3	1.5
	Other Black	0.5	0.8	0.2
Chinese		1.6	1.8	0.8
Other Ethnic Group		1.5	1.7	0.8

Table reproduced from http://www.neighbourhood.statistics.gov.uk/dissemination/ (2011)

Tower Hamlets is home to the third largest proportional populations of non-indigenous inhabitants in all of London. This is explained in part by the fact that the borough is home to the largest proportion of Bangladeshis in both London and England. South Asians account for 30.6% of the borough's population, compared with just 6% nationally. Of this group, over 20% are Bangladeshi, compared with 2.2% for the whole of London and 0.7% nationally. The prevalence of Bangladeshi residents in Tower Hamlets is almost thirty times greater than the national average, highlighting the unique nature of the local population profile.

Tower Hamlets' residents have a particularly young age profile too. The borough has the third largest proportion of 20-34yr olds nationally, accounting for 37% of all residents. Looking at 15-44yr olds, this age range accounts for 59% of the population, compared with 42% nationally (2011b). The borough also has the smallest proportion of 45-79yr olds in London, accounting for just 20% of all residents. The diverse ethnic profile is even more pronounced amongst the borough's younger residents. One third of the Bangladeshi community in Tower Hamlets are between 0-15yrs old. This group equates to 50% of all 0-15yr olds in the borough. White residents account for 35% of the same age bracket, equal to 14% of all white residents in the borough. The vast majority of Bangladeshi children in Tower Hamlets were born in the UK.

5.1.2 Socioeconomic Profile of Tower Hamlets

The socioeconomic profile of Tower Hamlets is very diverse. It is the second most divided borough in terms of income inequality, being home to two of the richest wards in the city as well as four of the poorest (2010). The low end of income spectrum can be explained in part by the large Bangladeshi population, traditionally consisting of predominantly unskilled workers. The higher end of the spectrum is explained by the borough's location with regard to the two affluent financial centres, Canary Wharf and the City of London's 'Square Mile'. According to the 2001 Census, Tower Hamlets is the highest ranked London borough in terms of claimants of Job Seekers Allowance and third for out-of-work benefit (2010), giving insight into the area's unemployment issues.

The national rate of child poverty is 21.3%. However, Tower Hamlets has the highest prevalence of child poverty in the country (2011). It is home to the top two nationally ranked parliamentary constituencies in terms of child poverty; Bethnal Green & Bow (57%) and Poplar & Canning Town (55%) (2011). Tower Hamlets is the borough in the country where more than half (57%) of the child population is living in poverty. This is a rate of poverty almost five times greater than the west London borough of Richmond upon Thames.

It is also the second most deprived borough in London, behind neighbouring Hackney, and the third most deprived in the UK. This is highlighted by the fact that 79% of child residents are in low income families. The online database Child Poverty Toolkit (2011) provides further information on indicators for low income families in the Tower Hamlets, presented in figure 5.1.

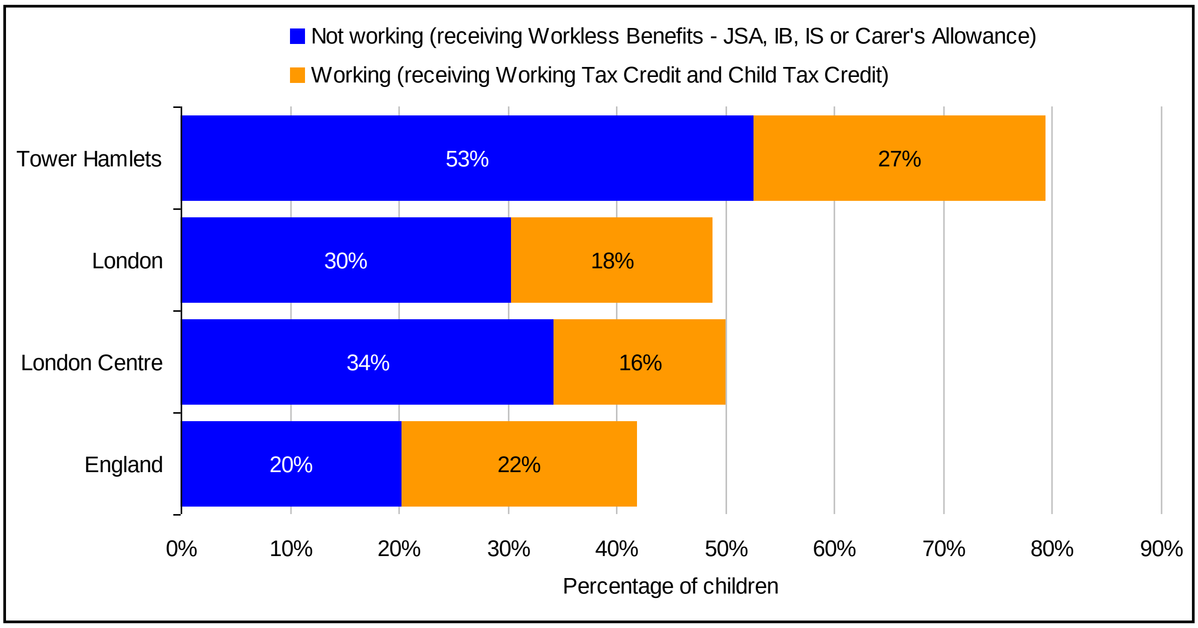


Figure 5.1 – Indicators of Children in Low Income Families in Tower Hamlets; Table reproduced from http://www.childpovertytoolkit.org.uk/Data-Tools (2011)

In the graph, the two bars combined for each area represent the total percentage of children in low income families. As stated, 79% of children in Tower Hamlets are in low income families. The inflated figure for Tower Hamlets is due to a combination of a high percentage of children without parents in employment (53%) and parents in low income jobs (27%). Both of these figures are significantly greater than London and national averages. Forty-eight percent of children in Greater London are in low income families, and 42% of children nationally are in low income families.

Statistics regarding housing further highlight the poor socioeconomic standing of Tower Hamlets and many of its residents. Tower Hamlets is one of the most densely populated areas in London (2011). It is the 320th borough in the country in terms of size, 19.77km^2 in area. This contrasts significantly with the population, ranked 58th nationally. Approximately 30% of all houses in the borough are overcrowded (2010), the fourth highest rate in London. This is somewhat symptomatic of its location in Inner London, as the other overcrowded boroughs are in Inner London. In sharp contrast, the Outer London boroughs of Bexley and Havering report levels of overcrowding close to 5%, six times lower than Tower Hamlets.

Further evidence of socioeconomic deprivation is provided by the results of the Research with East London Adolescents: Community Health Survey (RELACHS) (Rothon et al., 2010, Taylor et al., 2005, Viner et al., 2008, Viner et al., 2006). This large-scale epidemiological study, conducted between 2001 and 2003, gathered health-related information from almost 3,000 secondary schoolchildren in Tower Hamlets, as well as the neighbouring boroughs of Newham and Hackney. Taylor and associates (2005) reported overcrowding of 28% in their study sample. The questionnaire administered in this study also produced notable results regarding other indicators of social deprivation. Thirty percent of children did not have a family car, 48% were eligible for free school meals and 37% of those surveyed did not have either parent in employment.

These findings, the most comprehensive gathered to date in the area, confirm the government estimates presented here. Although Tower Hamlets is book-ended to the east and west by many highly prosperous financial institutions, their wealth is in stark contrast to the socioeconomic statuses of many of their neighbouring borough residents.

5.2 ETHNICITY AND SOCIOECONOMICALLY-DERIVED HEALTH INEQUALITIES

Looking beyond Tower Hamlets, Romeri and associates (2006) reported on the association between area deprivation and mortality, including cause of death, using data gathered from across England and Wales by the Office of National Statistics.

This study reported that increased mortality and all causes of death were consistently associated with area deprivation in all regions of England and Wales. The date rate for those in the top 5^{th} percentile for area deprivation was 1.7 times greater than for those in the bottom 5^{th} percentile. This difference increased to 2.8 times for those in the age range of 16 to 64 years. Similar trends were observed for the causes of death, including circulatory disease, ischaemic heart disease, stroke and cancer. The mortality rate was similar in all deprived areas, independent of region. However, the health inequalities between socioeconomic classes were smaller in London compared with the rest of the UK. This may be explained by the fact that London did often have the lowest mortality rate in each deprivation quintile.

The observations made by Romeri and associates are supported by those made by Woods and associates (2005) in another study using data from the Office of National Statistics. This study gathered information on deaths in England and Wales in 1997, 1998 and 1999 to predict the life expectancy for every ward in both countries and compare the results with the deprivation index for the wards. A regional north-south division was observed in terms of life expectancy. This observation was predominantly attributed to the distribution of income deprivation. Men and women from the most affluent fifth of wards had a life expectancy 5 years and 3.6 years, respectively, greater than those living in the most deprived fifth of wards. The results of this study confirmed the importance of material deprivation as a determinant of life expectancy in the UK.

Given the unique demographic profile of Tower Hamlets' residents, it provides a useful insight into health inequalities associated with ethnic minorities, area deprivation and poverty. According to the most recent national census (ONS, 2001), two thirds of Tower Hamlets' residents classified their health as 'good'. A similar health status was reported by 71% of London residents and 68.8% of the total population of England. Ten percent of people in Tower Hamlets reported their health as 'not good', compared with 8.3% in all of London and 9% in all of England. Tower Hamlets' residents therefore classify themselves as slightly less healthy than their London counterparts.

The national census (ONS, 2001) also provides information regarding life expectancy. The predicted values are poor, the 6^{th} and 5^{th} lowest in London for men and women, respectively. Men have a life expectancy of 76yrs, compared with 78.6yrs in all of London. Women, as expected, have a higher life expectancy of 80.9yrs, also lower than the London life expectancy of 83yrs. Tower Hamlets is joined by the other inner city boroughs of Hackney, Newham and Lambeth in having the highest rate of premature death in Greater London. The risk of premature death here is twice that of the traditionally affluent west London areas of Kensington and Chelsea.

More detailed statistics regarding health issues in the Tower Hamlets are not available through government or other publically available online databases. Further information is gathered primarily from research studies carried out in the locality. The Research with East London Adolescents: Community Health Survey (RELACHS) study is the primary source of epidemiological information available relating specifically to Tower Hamlets. It aimed to investigate many aspects of health and well-being. The study was carried out between 2001 and 2003 in 28 secondary schools in Tower Hamlets, Hackney and Newham, the highest, third and fourth highest rated boroughs in the country in terms of child poverty (2011). It involved 2,790 participants, taken from Years 7 (11-12yrs) and Year 9 (12-14yrs). Seventy-three percent of the participants were from ethnic minorities. Differences in health outcomes were investigated in terms of ethnicity. A second large-scale epidemiological study involving an ethnically diverse sample of London children was the Child Heart and Health Study in England (CHASE). This study was carried out amongst 5,000 primary school children in London, Leicester and Birmingham. The main outcomes measured were the prevalence of adiposity and its influence of cardiovascular and metabolic disease, as well as both diet and physical activity.

5.2.1 Adiposity in Tower Hamlets and Beyond

Investigating the role of socioeconomic status as a determinant of adiposity at a national level, Stamatakis and associates (2005) collated data from a 30 year period. Data regarding overweight and obesity was gathered in 1974, 1984 and 1994 from the National Study of Health and Growth, and from 1996 to 2003 from the Health Survey for England. Socioeconomic status was derived from the occupation of the head of the household.

For all children, the prevalence of overweight and obesity increased steadily between 1974 and 1997, accelerating considerably between 1997 and 2003. Using the 1974 data as a baseline figure, the odds ratio for obesity was 1.77 in 1994, 2.62 in 1997, 3.65

in 2001 and 4.25 in 2003. At all stages, a significant difference in obesity rates was visible between children of different social classes, a low socioeconomic status was consistently associated with increased rates of adiposity. The odds ratios of being overweight or obese were higher for children with parents employed in manual labour versus non-manual labour and children in low income households versus high income households.

Stamatakis and associates (2010) added to this research with updated information from 2007. The new data suggested that the trends in overweight had levelled off and trends in obesity had slowed considerably between 2003 and 2007 (OR 1.06). However, the socioeconomic gradient, evidenced initially in the 2005 report, had increased in recent years. Compared to data from 1997, the odds ratio for overweight in 2007 was 1.13 for children with a high SES, 1.25 for those with a middle SES and 1.88 for those children with a low SES. The evidence provided by these studies, of both increasing obesity rates across England and increased risk for those in lower socioeconomic classes, suggests that urgent interventions are required to address socioeconomic disparities in overweight and obesity.

Taylor and associates (2005) investigated the prevalence of overweight and obesity in Tower Hamlets as part of the RELACHS study. Adiposity, as determined by BMI, was examined in association with SES and ethnicity. Levels of overweight and obesity were established according Centre for Disease Control and Prevention (CDC) and International Obesity Task Force (IOTF) guidelines, but were expressed in terms of the latter cut-off points. Differences according to ethnicity were examined. The prevalence of overweight amongst girls ranged from 21% (Bangladeshi) to 40% (Black African), depending on ethnicity. Overweight amongst boys ranged from 16% (Pakistani) to 36% (Indian). Levels of obesity amongst girls were lowest for the Pakistani group (6%) and highest for Black Africans (12%). For boys, obesity levels were lowest for Black African boys (3%) and highest for their Black Caribbean counterparts (11%).

Overall, the prevalence of overweight and obesity reported in this study was higher than that of previous studies carried out in the UK. While slight differences occurred across ethnicities, the findings of this study suggest that the risk of obesity is a significant health risk in this East London population, regardless of gender or ethnicity.

Nightingale and associates (2011) also investigated differences in the prevalence of overweight and obesity according to ethnicity, using data gathered from CHASE. Adiposity was established through a number of anthropometric measures; skinfold thickness, BIA and BMI. The author did not classify participants as normal, overweight and obese, instead presenting BMI, skinfold thickness and BIA-determined %BF as continuous variables, compared across ethnicity.

This study suggested that South Asian participants had higher scores for both skinfold thickness and %BF, compared with their White counterparts. In contrast, South Asians reportedly had lower BMI scores than White participants. Black participants recorded opposite trends, scoring lower than White participants for both skinfold thickness and %BF, but higher for BMI. Although the study did not provide information regarding the prevalence of overweight and obesity, it did provide evidence of significant differences in adiposity levels based on ethnicity. This study called into question the choice of method used to compare adiposity in a multi-ethnic sample.

Although not derived from an East London-based sample, research has been carried out on Health Survey for England data looking at ethnic differences in levels of adiposity amongst young people (Saxena et al., 2004). This investigation stemmed from a government-backed statement that obesity interventions should be targeting children from ethnic minorities and low socio-economic statuses (CPA, 2006). Overweight and obesity were calculated for 5,679 children, using the IOTF BMI-determined guidelines.

Adiposity correlated significantly with gender and ethnicity. Amongst boys, Bangladeshis reported the lowest level of overweight (14.2%) and obesity (2.8%) compared with the general British population, 21.7% and 5.8%, respectively for overweight and obesity. For girls, Bangladeshis had the lowest rate of overweight amongst all major ethnicities (20.7% vs. 22.3%), but the same rate of obesity (5.8%) as white British girls. Although the study also compared adiposity according to socioeconomic status, no differences were observed. This study concluded that increased adiposity is very difficult to treat, so it should be prevented in childhood through diet and activity-driven interventions and policies. Ethnicity is an important determinant when designing such preventative strategies.

5.2.2 Cardiovascular and Metabolic Diseases in Tower Hamlets and Beyond

In a study derived from the CHASE study, Thomas and associates (2012) investigated the association between type 2 diabetes risk factors and both ethnicity and socioeconomic status. The study included 4,804 9-10 year old participants from Leicester, Birmingham and London. Twenty-four percent of participants were White, 25% were Black and 27% were South Asian. White and Black participants reported having a higher proportion of parents in managerial or professional jobs than their South Asian counterparts. The diabetes risk factors measured were insulin resistance, blood glucose, triglyceride and adiposity.

Associations were observed between SES and adiposity, insulin resistance and triglyceride for all participants, although the extent of the association differed between ethnic groups. For White participants, lower SES led to increases in fat mass index, insulin resistance and triglyceride, while for Black participants, lower SES was associated with lower ponderal index, insulin resistance and triglyceride. Amongst South Asians, no associations were observed between SES and any risk factors. The author concluded that ethnic differences in SES did not account for ethnic differences in type 2 diabetes risk factors. Ethnic differences in type 2 diabetes were actually greater in higher SES groups.

In another report from the wider CHASE study, Whincup and associates (2010) investigated the prevalence of predictors of type II diabetes mellitus in young people. Specifically, the study aimed to look at ethnic differences in risk factors associated with the disease, based on the theory that South Asian adults are at an increased risk of type II diabetes and central obesity compared to their White counterparts. It has also been suggested that the risk of contracting type II diabetes is strongly linked to increased adiposity for British South Asian adults (Hirschler et al., 2005, Misra et al., 2005). Previous studies have shown that British Bangladeshis, Indians and Pakistanis are particularly prone to cardiovascular disease and type 2 diabetes (Bhopal et al., 2002, Chowdhury et al., 2003). Mannan (2000) also points out that British Asians are four times more likely to get type 2 diabetes than white British.

Whincup (2010) gathered data regarding body composition, ethnic background, cholesterol, glucose and insulin levels as well as insulin resistance. Comparing white Europeans and South Asians, the latter group had higher %bf, glucose levels, insulin levels and insulin resistance. However, they also reported lower waist circumference and cholesterol levels. These findings add to the existing evidence that there is an increased risk of type II diabetes amongst South Asians. They had a higher prevalence of precursors for the disease, even though all the study's participants were apparently healthy and only around 10yrs old. This study also concluded that there is an urgent need to address precursors to metabolic diseases, particularly in ethnic minorities.

Similar findings were made in a previous study carried out by Whincup and associates (2002). It was conducted as part of the 10 Town Heart Health Studies that, much like East London, included a large South Asian representation amongst its 3,642 young participants. This study aimed to compare cardiovascular risks according to ethnicity, the main outcome measures including blood pressure, adiposity (BMI, WC), insulin levels and insulin resistance. South Asians reported increased diastolic blood pressure, insulin levels and insulin resistance, compared to white children. The South Asian group also reported a significantly stronger association between insulin sensitivity and adiposity than the white group. Again, Whincup concluded that the prevention of cardiovascular disease, through dietary and activity measures, needs to begin in childhood, particularly amongst South Asian children.

5.2.3 Physical Activity in Tower Hamlets and Beyond

Physical activity amongst children in East London and other areas with similar demographic profiles has been investigated in a number of studies. One such study was drawn from the much larger Research with East London Adolescents; Community Health Survey (RELACHS) (Viner et al., 2008). This study investigated physical activity levels amongst East London adolescents to establish the primary risk factors associated with chronic fatigue. Levels of physical activity and sedentary behaviour were measured by way of a questionnaire. Bangladeshi children accounted for 27% of those involved in the study. Overall, 51.1% of the study sample was classed as physically inactive. Twenty-nine percent engaged in less than two hours of sedentary behaviour per day but almost 27% engaged in more than four hours. Neither variable was presented according to ethnicity. High levels of sedentary behaviour were linked with persistent fatigue. The key finding from this study however, was the discovery of high levels of sedentary behaviour and physical inactivity amongst this East London population.

Rothon and associates (2010) also investigated physical activity as part of RELACHS, investigating its association with depressive symptoms in this particular study. Again, physical activity was measured via questionnaire, participants stating how many hours of sweaty activity they performed outside of school each week, answering ranging from zero to seven hours. An association was observed between activity levels and depressive symptoms, with each added hour of activity per week equalling an 8% reduction in the risk of depressive symptoms. More relevant to this study however, were the levels of activity. When asked how many hours of sweaty activity they performed outside of school, 11.5% of all children answered zero hours. Almost 29% of participants performed half an hour of activity, while 22.7% performed one hour of activity. Only 14.9% of all participants said that they participated in more than 4 hours of extra-curricular vigorous activity per week, of whom 8.7% performed between 4-6 hours. This is significantly less than the 62.8% of participants who only performed one hour or less of extra activity. It should be noted that children provided this information through questionnaire, a method of measurement for which they are more inclined to under-estimate their activity levels.

To investigate the role of ethnicity and socioeconomic status in terms of physical activity and sedentary behaviour, Brodersen et al (2007) used a large sample (n=4,320) from a number of London schools. This study measured socioeconomic status, ethnicity, anthropometrical measures and self-reported activity over a 5 year period, from the age of 11 to 16yrs. This age range was seen as important as it is around 11yrs that adolescents start to form independent adult patterns of activity. The author found that activity levels decreased as children got older, that Asian subjects were more sedentary than their white counterparts and that while physical activity levels were not related to socioeconomic status, sedentary behaviour was. The key findings of this study were a correlation between physical activity and ethnicity, even at the age of 11, and the significant association between sedentary behaviour and socioeconomic status. However, it should be highlighted that the use of self-report measures of physical activity and sedentary behaviour are a limitation of this study and those studies associated with RELACHS, given that self-reported methods of questionnaire are deemed unreliable for use with children (Michaud et al., 2002, Strycker et al., 2007, Treuth et al., 2003).

Ethnic differences in physical activity levels were also investigated as part of CHASE (Owen et al., 2009). A sample of 2,071 participants, primarily from white European, South Asian and black African-Caribbean ethnic backgrounds, provided accelerometer-determined physical activity data for at least one day. Moderate activity was defined as at least 2,000 accelerometer counts per minute, equal to a walking speed of $4km.h^{-1}$. On average, 64% of all participants participated in 1 hour or more of at least moderate intensity activity. However, this figure dropped to 54% when looking specifically at the South Asian group. The author deduced that the reduced prevalence of physical activity amongst South Asians, particularly moderate and vigorous activity, may play a role in this groups increased risk of metabolic conditions. Owen and associates concluded that the ethnic differences in physical activity and their implications for serious disease are an important issue requiring further research.

5.3 PRIMARY RESEARCH PROJECT

Tower Hamlets is home to a unique population, widely diverse in terms of both socioeconomic status and ethnicity. It is home to the largest proportion of Bangladeshis in the country, a group with a very young age profile (see section 5.1.1).

It also has the highest rate of child poverty in England (see section 5.1.2). Previous research suggests that the local population is at increased risk of cardiovascular and metabolic diseases. More recent studies, involving both the local and similarly-diverse populations throughout the UK, confirm that South Asian and other ethnic minorities are at increased risk of CVD, type II diabetes mellitus, obesity and mortality. Socioeconomic status and area deprivation are also widely linked to these health problems. Recent evidence suggests that the precursors to these diseases are already visible in the child population.

Along with diet, physical activity is widely cited as the primary preventative tool for obesity and related diseases. Unfortunately, local studies have also shown that South Asians are significantly less active than their white European counterparts. However, most of these studies have measured activity subjectively. No cross-sectional study has been conducted to date in the borough looking specifically at objectively measured physical activity levels of the South Asian and white European child population. Additionally, further investigation of the most recent step-count guidelines (Tudor-Locke et al., 2004) is required in a multi-ethnic study sample.

The main study hypothesis is that ethnicity-derived differences exist in the physical activity levels of schoolchildren in Tower Hamlets. A borough-wide study is warranted to investigate the presence of socioeconomic and ethnic disparities in health and provide a clearer insight into physical activity levels amongst children and adolescents. This study will investigate differences in activity levels according to ethnicity, socioeconomic status and also adiposity.

5.3.1 Research Question

The main research questions for this study are:

1. Do ethnic differences exist in the pedometer-determined physical activity levels of Year 7 students in Tower Hamlets?
2. Are socioeconomic status or ethnicity determinants of health status, as determined by activity and adiposity levels, in this population?

3. Is there an association between pedometer-determined physical activity and adiposity and is this association influenced by ethnic or socioeconomic differences?

These research questions will be addressed through the following aims:

i. What are the mean daily, weekday daily and weekend daily step count levels of this population?
ii. Do ethnic or socioeconomic differences exist in the step count levels of this population?
iii. Do gender, age or school differences exist in the step count levels of this population?
iv. What are the adiposity levels of this population, as measured by body mass index (BMI), waist circumference (WC) and bioelectrical impedance analysis (BIA)-determined percentage body fat (%BF)?
v. Does a significant association exist between pedometer-determined activity and adiposity and what are the significant correlates of this association?
vi. What are the step count recommendation-derived activity levels of this population and are the recommendations suitable for all ethnic groups?

The specific objectives of the study are:

- Collecting data regarding age, sex, ethnicity and socioeconomic status using a questionnaire
- Collecting seven days' pedometer data from all students involved in the study
- Measuring BMI, WC and BIA-determined %BF for all students
- Using recognised cut-offs to investigate both activity levels and levels of overweight and obesity
- Analysing and reporting significant differences in physical activity and adiposity data according to the socio-demographic variables
- Analysing and reporting significant correlations between activity and adiposity, controlling for significant socio-demographic covariables

CHAPTER 6 – METHODOLOGY

6.1 STUDY DESIGN

A cross-sectional observational design was chosen to realise the aims of the study. The study was designed so that data collection would be carried out over the course of two academic years, from Sept 2009 to July 2011, aiming to invite all Year 7 students attending secondary school Tower Hamlets.

The basic design of the study was developed from pilot research carried out in the 2008-9 academic year. Research testing was carried out in two secondary schools for the pilot study, hoping to achieve the same set of aims as the current research project, but on a smaller scale. Body composition was established using a combination of height and weight (to equate body mass index), waist circumference and bioelectrical impedance analysis (to determine percentage body fat). A self-report questionnaire was developed to establish socioeconomic status and ethnicity. Pedometers were employed to measure step counts and therefore determine physical activity levels. Specific details and techniques regarding recruitment, testing and analysis were reviewed at this stage with a view to refining the main study's design. Pilot testing also enabled the calculation of the estimated rate of testing. All data collection and analysis for the current study was conducted by the principal investigator (EMN).

6.2 STUDY SAMPLE

6.2.1 Recruitment

In line with the study's research question, the aim was to invite all students in Year 7 attending secondary school in Tower Hamlets to participate in the study. This equated to approximately 2,600 potential participants from the 15 secondary schools in the borough.

The study was specifically designed to employ staggered recruitment of schools over the course of the two academic years. As it was hoped to involve all 15 schools in the borough, it was envisaged that 8 schools would be recruited in year 1 and the remaining 7 schools in year 2, if all schools agreed to participate. This rate of testing was deemed feasible based on the projections developed from the pilot study.

Initially, contact details were gathered for all 15 schools and a letter outlining the nature of the study was sent to each school (addressed to the school head-teacher) inviting them to participate (appendix 2). At this stage, positive responses were received from three schools, indicating that they were happy to be involved in the study. Further contact was made with these three schools via email and phone. Face-to-face meetings were arranged and consent and projected testing dates were confirmed for all three schools.

These meeting were conducted with the head of the schools' P.E. department, the point of contact with the school throughout testing. At these meetings, the opportunity was taken to discuss the specific testing protocol. It was developed with a degree of flexibility, to account for the fact that there were would be certain unknown elements to testing at each school. While the primary aim of the study design was to collect reliable and accurate data, it was also important to make certain concessions to adapt to the conditions and environment at each school, and also to minimise interference with the normal P.E. class structure. Certain design details varied between schools to comply with their individual restraints, conditions and needs. However, a basic protocol for testing and collection of reliable, accurate and valid data was designed and complied with.

Testing (explained in detail in sections 6.3, 6.4 and 6.5) was conducted at these schools. Towards the end of this phase of testing, contact was re-attempted with the remaining schools that were eligible for participation.

For schools that did not respond to the initial attempts at recruitment, this was followed up by sending supplementary emails to the school's head-teacher and head of physical education (P.E.). Two schools expressed a positive interest at this stage and having agreed to participate, testing dates in the second half of the first academic year were agreed upon with both school. At the beginning of the second year, the recruitment process was repeated in the 10 schools that had yet to participate in the study. Letters and emails were also accompanied by attempted phone calls to each school's P.E. department. These methods resulted in the successful recruitment of a further three schools to the study. In the second half of the second year of testing, further unsuccessful efforts were made via telephone to contact the seven schools that had not expressed any interest to that date. Limitations regarding recruitment are discussed in detail in chapter nine.

Having received agreement from schools to participate, the recruitment of the individual students in Year 7 was conducted, performed in conjunction with the school's physical education (P.E.) department. Participant recruitment consisted of a short presentation from the principal investigator, given either to the whole of Year 7 during an assembly, or else given class by class during a P.E. lesson. Student's were told about the nature of the study, shown pedometers and also afforded the opportunity to ask any questions to the principal investigator. All students were then invited to participate, and given an information sheet for themselves (appendix 3), their parents or guardians (appendix 4) and a consent form (appendix 5). If students wished to participate in the study, they were instructed to have their consent form signed by a parent/guardian and it would be collected at school seven days later by the primary investigator.

6.2.2 Inclusion Criteria

All Year 7 students attending a secondary school in Tower Hamlets were eligible for inclusion in the study. The participants' actual home address was not recorded as it was assumed that the vast majority of students in Tower Hamlets' schools lived in the borough. This is based on the admissions policy for Tower Hamlets' secondary schools, giving preference to those children that live closest to the schools (THC, 2011a).

6.2.3 Exclusion Criteria

Participants were only excluded from physical activity testing if they suffered from a medical condition that inhibited their ability to perform ambulatory movement. This was established initially by asking P.E. teachers if anyone had inhibited movement and then informing potential participants of the exclusion criteria.

6.2.4 Ethical Approval

Ethical approval for the study was obtained from Queen Mary University Research Ethics Committee (appendix 6). Approval was also required and obtained from Tower Hamlets Children's Services to carry out research in any of the borough's schools (appendix 7). An enhanced criminal record bureau (CRB) check was also obtained by the investigator, a standard requirement when working in schools with young people in the United Kingdom.

6.2.5 Sample Size Calculation

The sample size required to observe a significant difference in the activity levels between the white and South Asian ethnic groups was calculated. A practically significant difference in physical activity levels between the two main ethnic groups was estimated as being 1,000 steps. This equates to a distance of approximately 0.5 miles or one tenth of a child’s daily activity. This represents both a substantial amount of activity and a practically significant difference between the two ethnic groups. Based on the findings of previous studies investigating step count differences according to ethnicity (Duncan et al., 2006, Margham et al., 2008), a standard deviation of 4,000 steps was applied. Using a proposed test power of 90% and two-sided significance level of 5%, the sample size of each ethnic group was calculated as 336. Accounting for the increased prevalence of white children in the borough (51% white versus 37% South Asian), the sample sizes were revised to represent their respective ratios (1.38:1), equalling 390 white participants and 284 South Asian participants.

6.3 QUESTIONNAIRE

Participants were first assigned a unique study number, as recorded onto a questionnaire form (appendix 8) filled out by the principal investigator. The design of the questionnaire was developed from the pilot study. Age was recorded and questions pertaining to ethnicity and socioeconomic status were completed.

The questionnaire was interview administered by the primary investigator. The potential option of allowing participants to complete the survey themselves was considered, but ultimately dismissed for a number of reasons. In terms of time management, it was thought quicker for the primary investigator to conduct the questionnaire. Children could potentially misinterpret the questions, thus leading to poor quality data. Also, the question regarding parental employment proved difficult for some participants to answer, as with the question regarding ethnicity. On occasion, children needed to be verbally instructed of their options in this instance. For example, instead of asking "what ethnicity are you?", it was sometimes more beneficial to ask "do you know what country your parents come from?". A recall effect, increasing the likelihood of eliciting a response as a result of an interviewer probing, would not be possible with self-report methods (Bowling, 2005).

Potential limitations do exist when employing an interview-based questionnaire as opposed to self-report. Probing from an interviewer can lead to interviewer bias, whereby an interviewee feels distracted and obliged to provide desirable responses (Bowling, 2001). Interviewees might also be less inclined to divulge sensitive information out loud (Bowling, 2005). This was addressed by asking participants questions safe in knowledge that other participants were not within range to hear their answers.

6.3.1 Ethnicity

Participants were asked which ethnic classification best describes them. Their answer was recorded by the principal investigator. Where ambiguity existed, participants were encouraged to describe their ethnicity to the best of their ability in accordance with the classification guidelines of the 2008 Health Survey for England (DoH, 2008). For the purpose of statistical analysis, participants were grouped according to four general categories. The first group, 'White', consisted of White British and White Other (Eastern European) participants. The second group, 'South Asian', consisted of Bangladeshi participants and South Asian Other (Pakistani and Indian) participants. The third group, 'Black', consisted of Black African and Black Caribbean participants. The final group was labelled the 'Other' group, including Turkish, and Other (East Asian and Central American) participants.

6.3.2 Socioeconomic Status

Socioeconomic status (SES) was established via a number of questions asked by the investigator. These questions were based on a questionnaire developed as part of the Health Behaviour in School-Aged Children (HBSC) Family Affluence Scale (FAS), as reported by Currie and associates (1997). Currie suggested that adding a number of indicators of socioeconomic status together, giving a child a composite score, was a reliable predictor of their household socioeconomic status. This score could then be translated directly into an ordinal scale, the Family Affluence Scale. This method led to the development of three components on the questionnaire; entitlement to free school meals, parental employment status and possession of household items. The household items were uniquely chosen; this was encouraged by Currie and associates (1997) with a view to personalising the FAS to the study sample.

The first question asked of participants was whether or not they were entitled to free school meals. Entitlement to free school lunches was used as the primary indicator of socioeconomic status as it is applicable nationally in the UK. This method has previously been employed as an indicator of SES (Sammons et al., 1997). Parents do not have to pay for their children's school lunches if they receive any of the following; income support, income-based Jobseeker's Allowance, support under Part VI of the Immigration and Asylum Act 1999, the guarantee element of State Pension Credit, Child Tax Credit provided they have an annual income no greater than £16,190 or Working Tax Credit 'run-on' (Directgov, 2011). In this instance, the answers to the question of whether participants were entitled to free school meals were coded for yes (0) and no (1).

Participants were also asked about their parents' employment status; did their father/mother work and if so, what job did they have? They were asked separately about their fathers' and mothers' employment status. Again, if ambiguity existed, it was reported that the participant did not know what their father's/mother's employment status was or that they were employed but they did not know what position they held. These answers were also coded; no (0), yes (1) and unknown (2).

Participants were asked a number of other questions on household items, each of which was coded for analysis. They were asked whether they had a television at home (1) or not (0), if they had the internet at home (1) or not (0), how many cars their family had (0,1,2...) and whether they shared a bedroom (0) or not (1). Using these three components and the coding system developed by Currie and associates (1997), each participant achieved a composite score from which socioeconomic status could be predicted.

6.3.3 Other Potential Variables

Information regarding the types of activity that participants did during a normal week was originally gathered early in the study. Specifically, participants were asked how many hours per week they spent cycling and swimming. The purpose of this question was to try and account for certain limitations associated with pedometers, mainly their inability to record cycling or swimming. As a pedometer worn correctly on the hip can only record ambulatory movement, it does not record movement due to cycling. Also, it is not possible to wear pedometers in water so they cannot be worn when swimming. As a result, if a child swims or cycles during the week, this activity will not be recorded by pedometer.

As a possible limitation of the study and argument against the use of pedometers, information regarding swimming and cycling was gathered to assess how much activity was unrecorded. It became clear, having gathered this information from a subsample in the first two schools involved in the study (n=270), that neither swimming nor cycling was a common activity amongst the study population. With this knowledge, pedometer data was gathered in confidence that certain activities were not going unreported.

Many school-level variables, under the umbrella of environmental correlates, are associated with physical activity. Consideration was given to collecting certain school-level variables with a view to assessing their effect on physical activity levels. In particular, school layout (incorporating details of the commute between classes), catchment area and length of PE class. No specific information regarding the first two variables was available. Students attending local secondary schools are required to be residents of Tower Hamlets, a small, densely populated area. As a result, in theory the potential catchment area, and daily commute to and from school, is similar for all schools involved in the study.

A cursory recording of length of PE class was made in all schools. In general, students had two periods of PE per week, equating to between 60 and 90 minutes. However, an interesting observation made from attending many PE classes was that the actual time spent performing PE varied greatly from class to class, and was usually significantly shorter than two periods. PE time was affected by many issues: time spent getting changed before/after PE class; commute from changing room to class location (or from school when class was off-site); time spent listening to instruction/being reprimanded (during which students were sedentary). As a result, even if the prescribed length of the PE class did vary considerably across schools, the actual amount of time that represented would be very difficult to quantify.

6.4 ANTHROPOMETRY

The collection of body composition data was completed during the course of a P.E. class. A list of all those agreeing to participate was gathered from the P.E. teacher at the beginning of a lesson. In twos, they were asked to step out of class for a few minutes. Testing took place either in an enclosed section of the hall that P.E. was taking place or in an adjacent room if space was an issue. Having completed the questionnaire, participants then had anthropometric (height, weight, waist circumference, bioelectrical impedance) measurements taken.

All anthropometric data was collected from each participant during the same testing session. Measurements were carried out in the same order for each participant; height, weight, waist circumference and then bioelectrical impedance. Prior to testing, participants were asked to remove both of their shoes and socks. Most participants were already in a P.E. kit consisting of shorts or tracksuit bottoms and a t-shirt. Participants wearing jumpers were asked to remove them for anthropometric testing.

6.4.1 Body Mass Index

Height and weight were measured using the standard procedure (WHO, 1995). The standing height of each participant was measured to the nearest millimetre (0.1cm) using a Seca Leicester portable stadiometer (height measure) (Seca Ltd, Hamburg) and weight measured to the nearest 0.1kg on a Seca 899 portable scales (Seca Ltd, Hamburg), grade 3 approved. BMI was then calculated as weight (kg) divided by squared height (m^2). BMI was also converted into a standard deviation score (z-score) using the revised 1990 British reference (Cole et al., 1995).

Using this figure for BMI, participants were then classified as either normal, overweight or obese. Although two main sets of guidelines exist, developed by the CDC and the IOTF, the latter were applied to this sample (Cole et al., 2000). These guidelines were chosen as they are deemed to be more universally applicable than the US-specific CDC guidelines. The IOTF cut-off points are age and gender specific, the relevant cut-off points displayed in a graph by Cole and associates (appendix 9). For the purpose of data analysis, participants were then coded according to their BMI-determined weight status; normal (0), overweight (1) or obese (2).

BMI was also presented as BMI z-score (standard score). All participants' BMI was expressed as an age and sex specific score, based on the distribution of BMI data from the UK 90 growth reference. The BMI z-scores were calculated in Microsoft Excel using a specific macro developed for use with the BMI UK 90 growth reference (Child Growth Foundation, Chiswick, UK).

6.4.2 Waist circumference

Waist circumference was measured, with the participant standing, at the 'natural waist' (a point midway between the tenth rib and top of the anterior superior iliac crest) using a non-elastic tape measure (Seca 201 ergonomic circumference measuring tape, Seca Ltd, Hamburg) (WHO, 1995). Participants were measured over their P.E. kit (thin t-shirt) and 0.5cm was taken off the measured value. This measurement was repeated to reduce the risk of measurement error. If the recorded values differed, a third measurement was taken and the mean value was used.

Children were classified as normal, overweight or obese based on UK specific waist circumference percentiles developed by McCarthy and associates (2001). Although no specific guidelines for overweight and obesity as determined by these percentiles were proposed, the author did suggest that the 85th and 95th percentile could be employed for overweight and obesity, respectively. However, these cut-off points classified an unexpectedly large proportion of participants as overweight and obese. As a result, the 91st and 98th percentile were used to represent overweight and obesity, respectively. For the purpose of data analysis, participants were then coded according to their WC-determined weight status; normal (0), overweight (1) or obese (2).

6.4.3 Bioelectrical impedance analysis

Percentage body fat measurements were obtained through the use of hand-to-foot bioelectrical impedance analysis (BIA). Resistance was measured using a bio-electrical impedance analyser (Bodystat 1500 MDD, Bodystat Ltd., Isle of Man, UK). Participants were instructed to lie supine on a firm surface (usually a gym mat) for at least 3 minutes with their legs and arms abducted. Source electrodes were placed on the dorsum of the right foot on the distal portion of the second metatarsal and on the right hand on the distal portion of the second metacarpal. Sensing electrodes were placed at the right anterior ankle between the tibial and fibular malleoli and at the right posterior wrist between the styloid processes of the radius and ulna. Once the participants were fully comfortable and had been lying still for 3 minutes, the measurement was taken.

The value recorded for impedance was applied to a formula to derive fat-free mass (FFM). The formula used in this study was initially developed by Clasey and associates in 2007 (2007), more recently published in 2011 (Clasey et al., 2011). The formula was validated through comparison with DXA, and was tested in an ethnically diverse sample of English children. As a result, it has recently been used in a study stemming from the Child Heart and Health Study in England (CHASE), providing further evidence that it is of use in a UK study sample (Nightingale et al., 2011) The specific formula was:

$$\text{FFM} = \frac{-7655 + 297(Ht) + \ 125(Wt) - \ 17.4(Imp)}{1000}$$

Fat mass (FM) was derived as the difference between FFM and body mass (BM). Percentage body fat was then calculated as (FM/BM)*100. Data obtained using this method was deemed outliers if the values were less than 3% body fat, as this would constitute the approximate value of 'essential fat' which is required for normal physiological functioning.

Ideally, hydration status should be controlled for as hydration levels do affect the accuracy of this test. This could be done by ensuring all participants did not drink for a specified period of time prior to testing. Alternatively, all testing could be conducted as the same approximate time, as hydration levels are known to fluctuate throughout the day. However, it was not possible to control for hydration status during the current study due to the practicalities of working in a school. It was not possible to normalise hydration levels across all participants, nor was it possible to dictate the time of day when testing would take place.

Children were classified as normal, overweight or obese based on age and gender specific percentage body fat reference curves developed for British children (McCarthy et al., 2006). Similar to WC, these guidelines did not provide specific cut-off points for overweight and obesity. The 85th and 95th percentiles were suggested. However, these cut-off points again seemed to overestimate the number of overweight and obese participants, particularly compared with BMI. As a result, cut-off points equating to the 91st and 98th percentile were used for overweight and obesity, respectively. For the purpose of data analysis, children were coded according to their BIA-determined weight status category; normal (0), overweight (1) or obese (2).

6.4.4 Reliability of Measures of Adiposity

Intra-rater reliability analysis was performed to establish the level of agreement among multiple repetitions of participants' key anthropometric measurements performed by a single rater. The specific measurements were height, weight, waist circumference (WC) and bioelectrical impedance analysis (BIA).

During large-scale field testing, a rater's ability to effectively carry out a particular measurement again and again is known as intra-rater reliability. The reliability can affect the accuracy of a test. Intra-rater reliability is an important concern for the measurement of anthropometric variables. Given that this study involves the measurement of height, weight, bioelectrical impedance and waist circumference, a protocol is necessary to establish intra-rater reliability of these variables.

During the second year of data collection, approximately 10% (n = 30) of study participants had their height, weight, waist circumference and bioelectrical impedance measurements taken twice during a testing session. All participants had height, weight, waist circumference and bioelectrical impedance measured in accordance with normal testing protocol. Towards the end of a testing session, 10% of the study sample was retested, applying the exact same testing protocol. This 10% were chosen randomly using a random number generator in Microsoft Office Excel. As a result, two sets of data for all four variables were recorded for 30 participants (appendix 10). This data was statistically analysed to assess reliability.

6.5 PHYSICAL ACTIVITY

At the end of the P.E. lesson, all those students participating in the study received a pedometer to record their physical activity levels.

6.5.1 Reliability of Pedometers

Two different models of pedometer were used, the NL-800 and NL-2000, both developed by New Lifestyle (Montana, USA). The pedometers differ slightly in that the NL-2000 can provide extra information, notably regarding estimated calories expended. This feature was not employed during testing so did not affect pedometer performance. Both model of pedometer employ the same technology to record steps taken. The NL-800 (figure 6.1) and NL-2000 are piezo-electric pedometers with a 7 day memory and in-built clock. They have previously been validated against direct observation and used effectively in other studies involving children (de Vries et al., 2006, Tudor-Locke et al., 2002). This particular brand of pedometer has previously been validated against direct observation for children (Duncan et al., 2007b). The validity of pedometers is discussed in more detail in section 3.3.

Figure 6.1 – NL-800 Pedometer

Intra-instrument and inter-instrument reliability of pedometers refer to the reproducibility or repeatability of this method of physical activity measurement (de Vet et al., 2003), covering test-retest reliability and variability between pedometers, respectively. The reliability of pedometers has previously been established as being very high in both a controlled and free-living environment (Graser et al., 2007, Jago et al., 2006). The results and implications of these and other similar studies are covered in more detail in section 3.3.

The intra- and inter-instrument reliability of the NL-800 and NL-2000 pedometers was investigated by means of a walking test. This test would also be used to measure the accuracy of pedometers. All reliability testing was conducted by a single investigator (EMN), in keeping with the protocol of the main study.

For this walking test, the investigator also acted as the participant (age=29yrs, height=190cm, weight=85.4kg), having reported no medical issues that would affect ambulatory movement. One single participant was employed to remove any inconsistency relating to gait and stride length. The participant wore four pedometers at once; two NL-800 pedometers and two NL-2000 pedometers. The pedometers were affixed to the waist band of their trousers, two at the right hip and two at the left hip. Previous studies have recommended that the hip is the optimal site for pedometer placement; allowing the wearer to affix and read it with ease, while also accurately recording ambulatory movement (Graser et al., 2007, Tudor-Locke et al., 2002).

The walking test consisted of the participant taking exactly 100 steps on an even surface and in a straight line. At the beginning of the test, all pedometers were reset while attached to the trousers. One hundred steps were taken, as confirmed by direct observation from the investigator/participant. The participant stopped moving at the completion of the 100th step, whereupon the step count reading was taken from each of the 4 pedometers. This exact protocol was repeated for the following four working days. The same four pedometers were affixed to the same sites and the walking test was carried out over the same course. The 100 steps were completed within 2-3 metres of each other for the 5 walking tests. This resulted in the collection of 20 pedometer readings (4 pedometers * 5 walking tests). This data (appendix 11) was then used to assess pedometer reliability.

6.5.2 Pedometer Protocol

Prior to distribution, all pedometers were checked for a number of issues. Battery life was monitored by checking for the presence of a flashing symbol representing low battery. If the symbol was displayed, the battery was replaced. This was particularly important as if the battery died during data collection, all the data would be lost. The time on the in-built clock was checked, this was essential as it dictated the start and end (00:00) of each 24hr period of data collection. Pedometers were also checked to ensure that they had the same unique number marked (written on stickers) both inside and out. This was done to identify which specific pedometer was used by each participant. The number was written on the outside of the pedometer, so that the number was recorded when pedometers were being distributed, and inside, in case the outer sticker fell off during testing. Once all these issues were checked, pedometers were sealed using zip-ties. This was done for two reasons; to reduce the risk of reactivity and ensure that pedometers were not reset or tampered with in any way.

Participants were first instructed on the use of pedometers and encouraged to ask any question before the pedometers were distributed. This was due to concerns that it would be difficult to maintain participants' full attention once pedometers had been handed out. Instruction were given on how to wear pedometer; attached to the waist band of their trousers/skirt midway between the midline and the right hip, and shown how to secure this with the secondary clip (figure 6.2).

Figure 6.2 – Pedometer attached to waist band at right hip

Participants were instructed not to put the pedometer into a pocket. Participants were encouraged to wear their pedometers at all times; from as soon as they got up in the morning until they went to sleep at night time. They were specifically instructed to remember to wear the pedometer if they changed their clothes after school and at the weekend. They were also instructed not to get their pedometer wet; not to wear it while swimming, showering or while outdoors in wet conditions. Once all queries regarding pedometers were addressed, they were distributed. The investigator individually handed out pedometers to each participant, noting who received which number pedometer and also helping participants to attach the pedometer for the first time. Participants were instructed to return their pedometers to the instructor (sometimes via form teacher or PE teacher) after 7 days. Pedometers were then collected by the primary investigator, opened and step count data recorded. Seven readings were displayed by the pedometer, one for each of the last seven days of complete data collection. The data was entered into a spreadsheet.

Current guidelines, widely adopted by many studies involving children, suggest that boys and girls should reach 15,000 and 12,000 steps per day, respectively (Tudor-Locke et al., 2004). These guidelines were also used in this study to classify participants according to their activity status. Although these guidelines still require cross-validation (see section 2.4.4), they remain the most commonly employed method of classifying pedometer step counts. They are the deemed the most suitable guidelines to use in the current study, particularly for the purpose of comparison with results from other similarly designed high quality studies.

Participants were coded as being active (1; taking a mean daily step count greater than 12,000/15,000 steps for girls/boys) or inactive (0; taking less than 12,000/15,000 steps per day).

Compliance with the pedometer protocol was measured in a subsample of the study population by recording the number of children that wore their pedometers each day during the school week. Having distributed the pedometers to a group of students, the principal investigator visited their form class over the following four school days, recording what percentage of participants wore their pedometers each day.

6.5.3 Data Management

A lack of universal agreement exists regarding the optimal number of days that pedometer data should be collected in a cross-sectional study. Previous studies investigating this issue have done so by investigating day-to-day variability in activity behavior within individual participants. This variability was measured using either coefficient of variables (CV) across an increasing number of days (Vincent and Pangrazi, 2002) or intra-class correlation coefficients (ICC) (Tudor-Locke et al., 2009). Vincent and Pangrazi reported day-to-variability of 23% across 4 days. Given the inherent variability for this measure, 4 days was proposed as a sufficient number of days to collect representative data. Tudor-Locke and associates measured the ICC for incremental days, as it improved with increasing number of days. It rose from 0.65 for 2 days to 0.87 for 8 days. The author again conceded that some variability was inherent so given the study's findings, suggested that 2 days of pedometer data was sufficient. As one of the leading authorities in this area (Tudor-Locke et al., 2009), it was decided to use the guidelines suggested by Tudor-Locke and associates, so two days of valid pedometer data was deemed sufficient for inclusion in this study. ICC values were calculated for the activity data collected with a view to ensuring day-to-day variability was within the accepted range.

The potential for unusually extreme step count data required consideration. Outliers, extremely low or high mean daily step count values, can occur for a number of reasons; faulty equipment, erroneous data recording , erroneous data entry or participant reactivity (Rowe et al., 2004). Outlier data can also be valid, occurring as a result of an extreme member of a population sample. Although addressed in a limited number of studies (Craig et al., 2010, Rowe et al., 2004), no widely accepted guidelines for the treatment of outliers currently exist. Rowe and associates (2004) were the first to propose potential cut-off points for outliers, a low of 1,000 steps and a high of 30,000 steps. As previously discussed in section 3.3, these cut-off points were based on prior testing experiences and hypothetical situations of extremely active and inactive children. Rowe's 'rule' was adopted for the purpose of data analysis in this study. All data was scanned for outliers less than 1,000 steps or greater than 30,000 steps and where found, these specific day entries were removed from analysis.

Reactivity was measured by comparing the variability between the first full day of step count data and the mean daily step counts for all participants. An ICC >/= 0.8 was deemed acceptable to suggest that reactivity did not exist (Portney and Watkins, 2000a).

6.6 STATISTICAL ANALYSIS

Data were analysed using Microsoft Office Excel 2007 and SPSS version 17.0 for Windows (SPSS Inc., Chicago IL). The complete activity and anthropometric data sets were tested for normality using a Shapiro-Wilk test, measuring skewness and kurtosis and also through visual observation of Boxplots and histograms. For post-hoc tests between subgroups, Levene's test of equality of variance was conducted, as homogeneity of variance is an assumption of parametric analysis. If the data passed the test, parametric analysis was employed for post-hoc tests. However, if the data failed the test, non-parametric analysis was employed.

A chi-squared analysis was performed to investigate associations between indicators of socioeconomic status. The intra-rater reliability of anthropometrical measurement techniques was assessed by way of pairwise comparison and Pearson's correlation coefficient between the first and second round of testing. A Pearson's correlation coefficient of between 0.8 and 1.0 was deemed sufficient to establish reliability (Portney and Watkins, 2000a).

Potential clustering of both activity and adiposity data according to variables unrelated to the study's research questions was considered. In particular, potential school-level variables were investigated. To account for potential clustering, significant differences of the dependent variables (BMI/BMI Z-score/WC/%BF and mean daily/mean weekday/mean weekend daily step counts) according to class, school, year of testing, season of testing and provision of activity data were all investigated. Where significant associations were observed, these confounding variables were included in multivariate analysis.

For bivariate and multivariate analysis involving anthropometric measures, BMI, BMI z-score, WC and %BF were treated as dependent variables. Significant differences between anthropometric measures according to age, sex, ethnicity, socioeconomic status and school were assessed by Student's t-test or ANOVA. Where Levene's test of equality of variance was failed, Mann-Whitney U-tests or Kruskal-Wallis ANOVAs were applied instead. For ANOVA, where statistical significant differences were observed, Tukey's or Tamhane's post-hoc tests were applied. Multivariate analysis was conducted by way of stepwise regression, investigating the combined influence of significant independent variables on the dependent anthropometric measures. Where Levene's test of equality of variance was failed, data were transformed using log transformations in order to meet the assumptions of regression analysis.

Intra-instrument reliability for pedometers was established by a combination of measurements, comparing standard error, coefficient of variation and 95% limits of agreement across five days. Reactivity was established by measuring the intra-class correlation the first full day of step count data and the mean daily step counts for all participants.

For bivariate and multivariate analysis of activity data, mean daily, weekday daily and weekend daily step counts were treated as dependent variables. As with anthropometric measures, significant differences in mean pedometer step counts according to age, sex, ethnicity, socioeconomic status and school were assessed by Student's t-test or ANOVA. Where Levene's test of equality of variance was failed, Mann-Whitney U-tests or Kruskal-Wallis ANOVAs were applied instead. For ANOVA, where statistical significant differences were observed, Tukey's or Tamhane's post-hoc tests were applied. Similarly, multivariate analysis was conducted by way of stepwise regression, investigating the combined influence of significant independent variables on mean step count values (daily, weekday daily and weekend daily). Where necessary, log transformation of the dependent variable was conducted.

The association between adiposity and physical activity was established by Pearson's correlation. For all statistical analyses, a p-value less than 0.05 was used to indicate statistical significance.

CHAPTER 7 – RESULTS I

7.1 PARTICIPATION

7.1.1 Recruitment

Study participants were recruited from eight of the fifteen secondary schools in the borough. This represents 53% of schools. There were 1385 potentially eligible students across the 8 schools invited to participate. A total of 884 students agreed to take part in the study. This represents a recruitment rate of 64%. The individual student recruitment rates for all eight schools are presented below (table 7.1).

Table 7.1 - Recruitment Success from All Participating Schools

School*	Total in Year 7 (2011a)	No. Recruited (m/f)	Recruitment Rate (%)
Oaklands	125	122 (66/56)	97.6
Morpeth	240	152 (78/74)	63.3
Bishop Challoner Boys	120	75 (75/0)	62.5
Bethnal Green Tech.	180	133 (104/29)	73.9
Stepney Green Boys	180	140 (140/0)	77..8
Bow Boys	150	102 (102/0)	68.0
Bishop Challoner Girls	150	132 (0/132)	88.0
St. Pauls Way	240	28 (19/9)	11.7
Total	**1385**	**884 (584/300)**	**63.8%**

* Schools ordered chronologically according to testing date

Five of the schools were recruited and included in testing during the first year. By the end of the first year of testing, 74% of all students in those five schools agreed to participate in the study. This figure decreased to 49% for the second year of testing due to the inclusion of a school where only 12% of the students in Year 7 were successfully recruited into the study. Three of the eight schools involved in the study were boys' schools, compared with just one girls' school and four mixed-sex schools.

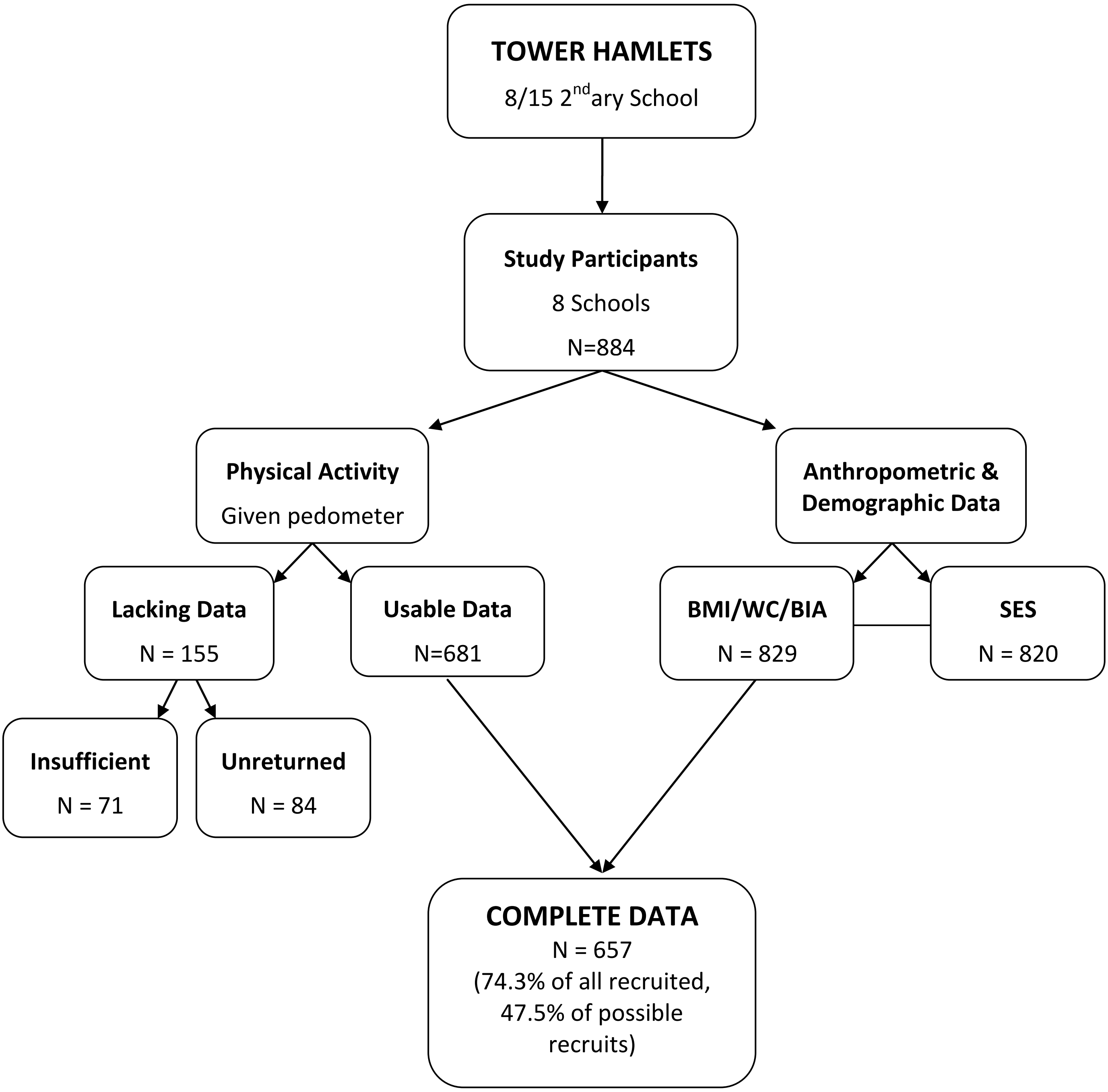


Figure 7.1 – Flow chart documenting recruitment and data collection across the study

Some amount of data, either demographic, activity, anthropometric or a combination of these three categories, was gathered from 884 participants. Usable physical activity data were provided by 681 participants, while anthropometric and demographic data were provided by 829 participants. A complete data set was available for 657 participants (figure 7.1).

Table 7.2 provides a breakdown of the number of participants providing complete data sets according to sex and ethnicity.

Table 7.2 – Number of Participants Providing Data

		Boys		Girls		All	
		n	%	n	%	n	%
No. of children in classes surveyed*		-		-		**1385**	
Number enrolled in study	White	89	15	85	28	174	20
	S.Asian	398	69	180	60	578	65
	Black	89	15	32	11	121	14
	Other	8	1	3	1	11	1
	Total	**584**		**300**		**884**	
Full set anthropometric data	White	83	16	79	28	162	20
	S.Asian	375	70	165	60	540	67
	Black	69	13	32	11	101	12
	Other	8	1	2	1	9	1
	Total	**535**		**278**		**812**	
Full set SES data	White	87	16	84	29	171	21
	S.Asian	368	68	167	59	535	65
	Black	80	15	32	11	112	13
	Other	7	13	2	1	9	1
	Total	**542**		**285**		**827**	
Given Pedometer	White	82	15	78	28	160	19
	S.Asian	381	69	169	60	550	66
	Black	86	15	30	11	116	14
	Other	8	1	2	1	10	1
	Total	**557**		**279**		**836**	
Returned pedometer with usable data	White	62	14	65	28	127	19
	S.Asian	313	69	140	61	453	67
	Black	69	15	22	10	91	13
	Other	8	1	2	1	10	1
	Total	**452**		**229**		**681**	
Full data set	White	58	14	65	28	123	19
	S.Asian	307	71	138	61	445	68
	Black	58	14	22	10	80	12
	Other	7	1	2	1	9	1
	Total	**430**		**227**		**657**	

*assuming no children absent from school

Pedometers were received by 95% of participants, accounting for almost 70% of South Asian boys and 60% of South Asian girls (table 7.2, above). Forty-eight participants were not given pedometers as although they provided anthropometric data, they were not present when pedometers were distributed. As can be seen in figure 7.1, 681 (77%) of all participants provided valid data physical activity data for at least two days. Seventy-one participants (8%) returned their pedometers but did not record at least two full days of physical activity data; these data were not included in analysis. A further 84 participants (10%) failed to provide any activity data at all. This represents participants that lost or broke their pedometers, as well as those that failed to wear their pedometers on at least two of the seven days. Physical activity data outside pre-determined outliers, less than 1000 steps and greater than 30000 steps daily, was also excluded from analysis.

Eight hundred and twenty nine participants (94%) provided anthropometric data. Of this group, 9 participants did not provide information on bioelectrical impedance. This occurred due to participants wearing tights and thus being unable to attach electrodes to their feet. Therefore, bioelectrical impedance analysis was performed on 93% of all those recruited for the study. Information regarding sex, ethnicity and age was gathered from all 884 participants. Information pertaining to socio-economic status (eligibility to free school meals, parental occupation, number of cars at home, internet access at home, shared bedroom) was gathered from 829 (94%) participants (see questionnaire, appendix 8).

Table 7.2 shows that of the 430 boys that provided a complete data set, over 70% were South Asian, while White and Black participants accounted for 14% each. Amongst the 227 girls that provided complete data sets, 61% were South Asian, 28% were White and 10% were Black.

7.1.2 Participant Demographics

Demographic outcome measures for all participants (11.6 ± 0.6 years old) are displayed in table 7.3, including age, gender and ethnicity (n=884) and indicators of socioeconomic status (n = 829).

Almost two-thirds (n=584) of all those recruited for the study were boys, compared with 300 girls. This is due, in part, to two reasons. Firstly, while three of the eight schools involved in the study were boys' schools, providing 317 of the male participants, only one of the schools was a girls' school, accounting for 132 girls. The four single-sex schools provided 449 (50.8%) of the total study sample. Secondly, of the outstanding 435 participants from the four mixed-sex schools, 267 (61%) were boys and 168 (39%) were girls. These 435 participants were recruited from a potential 785 students, representing a recruitment rate of 55%. Information is not available regarding the sex-specific breakdown of that potential group.

Table 7.3 – Demographics Outcome Measures for All Study Participants

		TOTAL		BOYS		GIRLS	
		n	%	n	%	n	%
Total		884	100	584	66.1	300	33.9
Age	11	390	44.1	256	43.8	134	44.7
	12	489	55.3	324	55.5	165	55
	13	5	0.6	4	0.7	1	0.3
Ethnicity	White	174	19.7	89	15.2	85	28.3
	S. Asian	578	65.4	398	68.2	180	60.0
	Black	121	13.7	89	15.2	32	10.7
	Other	11	1.2	8	1.4	3	1.0
Receiving Free school meals?	Yes	458	55.2	309	57	149	51.9
	No	371	44.8	233	43	138	48.1
Father employed / full-time education	Yes	383	46.3	240	44.3	143	49.8
	No	415	50	289	53.3	126	43.9
	Not known	31	3.7	13	2.4	18	6.3
Mother employed / full-time education?	Yes	105	12.6	68	12.5	37	12.9
	No	638	77	444	81.9	194	67.6
	Not known	86	10.4	30	5.5	56	19.5
Both parents employed / full-time education		98	11.8	64	11.8	34	11.8
Neither parent employed / full-time education		404	48.7	284	52.4	120	41.8
TV at home?	Yes	826	99.6	540	99.6	286	99.7
	No	3	0.4	2	0.4	1	0.3
Internet at home?	Yes	630	76	397	73.2	233	81.2
	No	199	24	145	26.8	54	18.8
Car(s) at home?	Yes	446	53.8	286	52.8	160	55.7
	No	345	41.6	228	42.1	117	40.8
	2+	38	4.6	28	5.2	10	3.5
Shared bedroom?	Yes	655	79	417	76.9	238	82.9
	No	174	21	125	23.1	49	17.1

7.1.2.1 Ethnicity

The specific ethnic breakdown of all participants in the study is presented in table 7.4 below.

Table 7.4 – Ethnic Profile of the Study Population

Ethnicity	Total		Boys		Girls	
	n	%	n	%	n	%
White British	169	19.1	85	14.6	84	28.0
White Other	5	0.6	4	0.7	1	0.3
- WHITE	**174**	**19.7**	**89**	**15.3**	**85**	**28.3**
Bangladeshi	485	54.9	339	58.0	146	48.7
South Asian Other	93	10.5	58	9.9	35	11.7
- SOUTH ASIAN	**578**	**65.4**	**397**	**67.9**	**181**	**60.4**
Black African	86	9.7	66	11.3	20	6.7
Black Caribbean	35	4.0	23	3.9	12	4.0
- BLACK	**121**	**13.7**	**89**	**15.2**	**32**	**10.7**
Turkish	8	0.9	6	1.0	2	0.7
Other	3	0.3	2	0.3	1	0.3
- OTHER	**11**	**1.2**	**8**	**1.3**	**3**	**1.0**
TOTAL	**884**	**100**	**584**	**100**	**300**	**100**

Based on the ethnic profile of the study population, participants were grouped according to four general categories for the purpose of analysis. The first group, 'White', consisted of White British and White Other (Eastern European) participants. The second group, 'South Asian', consisted of Bangladeshi participants and South Asian Other (Pakistani and Indian) participants. The third group, 'Black', consisted of Black African and Black Caribbean participants. The final group was labelled the 'Other' group, including Turkish, and Other (East Asian and Central American) participants.

The 'White' group accounted for 19.7% of the total study population, equating to 15% of all boys and 28% of all girls. The 'South Asian' group accounted for 65% of the total study sample, 55% of whom were Bangladeshi. The South Asian group contained 68% of all boys in the study, and 60% of all girls too. As discussed in section 5.1.1, Bangladeshi children account for 50% of the borough's 0-15yrs population, while White children account for 35% of the same group (THC, 2011b). While the size of the Bangladeshi group mirrors the overall borough population, the size of the White group was less than predicted. This may be explained by the specific schools that were recruited for this study; the majority of white students may attend some of the other seven schools not included. The 'Black' group accounted for 14% of the total study population, 15% of all boys and 115 of all girls. Of the 'Other' ethnicities, eight were from Turkey, two were of East Asian ethnicity and one was Cuban.

7.1.2.2 Indicators of Socioeconomic Status

The indicators of socioeconomic status are presented in table 7.3. The indicators include entitlement to free school meals, parental employment status, having a television, the internet or car(s) at home and also sharing a bedroom.

Overall, parental employment was low. While 415 participants reported not having a father in employment and 638 did not have a mother in employment, 404 of participants (49%) had neither parent in employment. In contrast, 98 participants (12%) had both parents in employment; this figure included 26% of all fathers in employment but 93% of all mothers in employment.

Almost every participant (99.6%) reported having a television at home, while 76% of participants had internet access at home too. Nearly 54% of participants reported having a car at home, while a further 38 participants (5%) had two or more cars. A slightly higher percentage of girls (83%) claimed to share a bedroom at home than boys (77%).

Of the 458 participants entitled to free school meals, 373 (81%) did not have a father in employment. But 85% (314) of participants that were not entitled to free school meals did have a father in employment. The association between these two indicators was significant (χ^2 test $p<0.001$, Cramer's V coefficient = 0.709). This association was expected, given that parental employment status is one of the main deciding factors for entitlement to free school meals.

Almost 94% (430) of participants receiving free school meals reported that their mother was not in employment. Of the participants with a mother in employment, only 23 (22%) also received free school meals. Further analysis suggested a moderately strong association between these two variable (χ^2 test $p<0.001$, Cramer V coefficient = 0.453).

There were 294 participants with a family car that were not entitled to free school meals and 291 participants with no family car that were entitled to free school meals. Of the 38 participants that claimed to have 2 or more family cars, 23 (61%) did not receive free school meals while 15 (40%) were entitled to them. Overall, the association between these two indicators was significant (χ^2 test $p<0.001$, Cramer V coefficient = 0.495).

The questions regarding family affluence were coded to reflect socioeconomic status and the combined score from the five answers provided a composite score ranging from 0 to 6 for low to high SES. It was originally planned to include two more questions regarding parental employment (father and mother) into the composite score. However, given the poor response rate to the questions (103 participants responded that they did not know what either or both of their parents' employment status was), it was not possible to interpret these questions so they were completely removed from the composite score.

The composite scores for SES for all participants are presented in table 7.5, below.

Table 7.5 – Composite Score for Socioeconomic Status According to Sex and Ethnicity

		0		1		2		3		4		5		6	
		n	%	n	%	n	%	n	%	n	%	n	%	n	%
BOYS	**White**	0	0	7	9	20	25	17	21	28	35	8	10	1	1
	S. Asian	0	0	43	12	103	28	95	26	77	21	46	12	9	2
	Black	0	0	21	26	12	15	8	10	34	43	5	6	0	0
	Other	0	0	1	12	0	0	4	50	3	38	0	0	0	0
	TOTAL	**0**	**0**	**72**	**13**	**135**	**25**	**124**	**23**	**142**	**26**	**59**	**11**	**10**	**2**
GIRLS	**White**	0	0	16	20	23	28	8	10	30	37	3	4	1	1
	S. Asian	1	1	16	9	37	22	30	17	71	41	14	8	3	2
	Black	0	0	7	23	4	13	2	7	15	48	3	10	0	0
	Other	0	0	0	0	0	0	1	33	2	67	0	0	0	0
	TOTAL	**1**	**0**	**39**	**14**	**64**	**22**	**41**	**14**	**118**	**41**	**20**	**7**	**4**	**1**
COMBINED		**1**	**0**	**111**	**13**	**199**	**24**	**165**	**20**	**260**	**31**	**79**	**10**	**14**	**2**

7.1.2.3 Ethnicity and SES Indicators

The relationship between ethnicity and socioeconomic status indicators was also explored, as presented in table 7.6 and table 7.7.

Looking firstly at participants that were reported as being entitled to free school meals, South Asians had the largest relative representation (58%, n=315), closely followed by White participants (56%, n=90). In contrast, the Black group had the highest relative representation in terms of participants that were not entitled to free school meals (57%, n=63). A χ^2 test confirmed that there was a significant association between these variables (p=0.022), but a Cramer's V coefficient of 0.096 indicated that the association was very weak, as evidenced by the similar percentages between groups.

Table 7.6 – Prevalence of Socioeconomic Variables According to Ethnicity

		White		S. Asian		Black		Other	
		n	%	n	%	n	%	n	%
Receiving Free school meals?	Yes	90	56	315	58	48	43	5	45
	No	72	44	230	42	63	57	6	55
Father employed / full-time education?	No	81	50	286	53	44	40	4	35
	Yes	74	46	237	44	66	60	6	55
	Unknown	7	4	22	4	1	1	1	9
Mother employed / full-time education?	No	122	75	421	77	88	79	7	64
	Yes	20	12	76	14	7	6	2	18
	Unknown	20	12	48	9	16	14	2	18
TV at home?	No	2	1	1	0	111	100	11	100
	Yes	160	99	544	100	-	-	-	-
Internet at home?	No	38	24	121	22	37	33	3	27
	Yes	124	77	424	78	74	67	8	73
Car(s) at home?	No	74	46	222	41	45	41	4	36
	Yes	81	50	292	54	66	60	7	64
	2 +	7	4	31	6	-	-	-	-
Shared bedroom?	Yes	130	80	419	77	99	89	7	64
	No	32	20	126	23	12	11	4	36

Trends in father's employment status according to ethnicity are also presented in table 7.6, above. Amongst the White ethnic group, 81 participants (50%) reported that their father was unemployed, while 74 participants (46%) did have a father in employment.

A similar pattern was observed amongst the South Asian ethnic group. Fifty-three percent (n=286) of this group did not have fathers in employment, while 237 participants (44%) did. The Black ethnic group differed, with the majority of participants (60%, n=66) reportedly having a father in employment.

Similar proportions of participants with mother's in employment were discovered across all three ethnic groups. Almost 79% of the Black group did not have a mother in employment, compared with 77% for the South Asian group and 75% for the White group. Similarly, 14% of South Asian participants did have a mother in employment, compared with 6% of the Black group and 12% of all White participants. Given that there are similar trends across ethnicities, a chi-square test confirmed that there was no significant association between ethnicity and mother's employment status (p=0.09).

The association between socioeconomic status, as defined by composite score, and ethnicity was also investigated. One-way ANOVA indicated no significant differences between ethnic groups, as presented in table 7.7.

Table 7.7 Mean and 95% Confidence Interval Values for Composite Score of SES by Ethnicity

		N	Mean (95% CI)
ETHNICITY:	**White**	162	2.98 (2.79-3.18)
	S. Asian	545	3.08 (2.97-3.19)
	Black	111	2.94 (2.68-3.2)
	Other	11	3.27 (2.67-3.88)
	Total	829	3.04 (2.96-3.13)

7.2 ADIPOSITY

7.2.1 Tests for Normality

Kolmogorov-Smirnov and Shapiro-Wilks tests of normality were run for all anthropometric variables. Although both tests suggested that all of the variables were not normally distributed, these tests are less reliable when applied to larger sample sizes, so the results should be treated with caution as n > 600. Values for skewness and kurtosis were established for all variables (table 7.8). Skewness ranged from -0.496 to 0.795 while kurtosis ranged from -0.495 to 0.712. Boxplots for all four variables are presented below (figure 7.2) and histograms were also visually observed (appendix

12). These graphs suggested that all variables (BMI, BMI z-score, WC and %BF) had a 'normal enough' profile to employ parametric analyses for all of these variables. For the purpose of specific analyses between subgroups, Levene's test for homogeneity of variance was used to check the assumption of equality of variance. Where variance was equal, parametric analysis was applied for post-hoc tests, and non-parametric analysis applied where variance was not equal.

Table 7.8 – Tests to establish use of parametric or non-parametric analysis

	BMI	BMI Z	WC	%BF
Kolmogorov-Smirnov (p)	<0.001	<0.001	<0.001	<0.001
Shapiro-Wilk (p)	<0.001	<0.001	<0.001	<0.001
Skewness	0.795	-0.496	0.709	-0.064
Kurtosis	0.712	0.094	0.373	-0.495

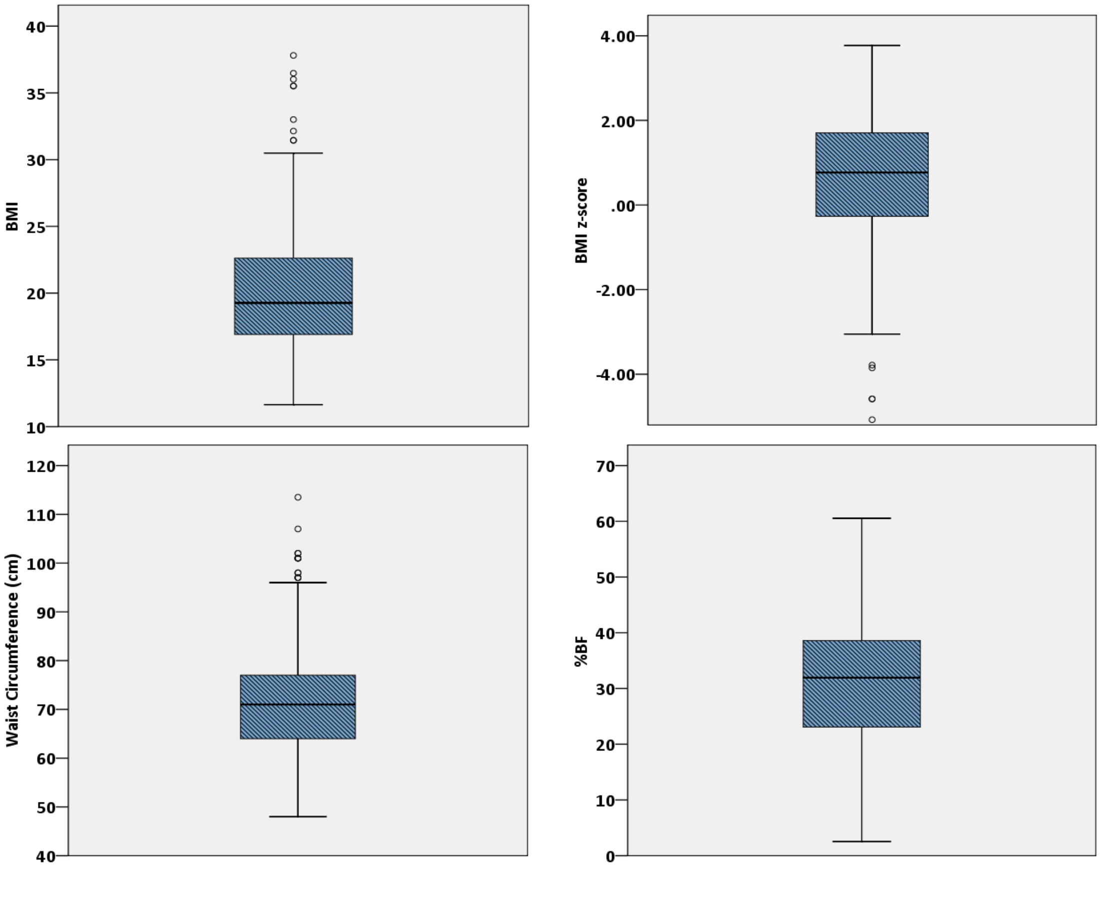


Figure 7.2 – Boxplots for all BMI, BMI z-score, WC and %BF data

7.2.2 Intra-Rater Reliability

As there were only two samples for each measure, reliability was examined using Pearson's correlations and paired samples t-tests. The output from these tests is presented in table 7.9. No significant differences were established between raters and all variables showed very close correlation between forms, the lowest being $r = 0.996$. These results suggest that intra-rater reliability was very high.

Table 7.9 – Descriptive Data for Intra-Rater Reliability of Anthropometrical Measurements

	n	Test 1		Test 2		Sig. (2-tailed)	Pearsons	
		Mean	S.D.	Mean	S.D.		Correlation	Sig.
Height	30	147.35	7.03	147.38	7.03	0.423	0.999	<0.001
Weight	30	40.61	8.19	40.60	8.20	0.255	1.000	<0.001
WC	30	72.00	7.78	72.03	7.61	0.823	0.995	<0.001
Impedance	30	882.43	77.89	882.13	79.96	0.780	0.998	<0.001
%BF	30	35.37	7.02	35.33	7.06	0.477	0.999	<0.001

7.2.3 Association between Anthropometrical Variables

Table 7.10 – Pearson's Correlations displaying the Association between Anthropometrical Variable

			BMI	Waist Circumference	%BF	BMI z-score
TOTAL	BMI	*r*	1	0.798**	0.921**	0.939**
		n	830	830	814	830
	Waist Circumference	*r*	-	1	0.747**	0.780**
		n	-	830	814	830
	%BF	*r*	-	-	1	0.919**
		n	-	-	814	814
	BMI z-score	*r*	-	-	-	1
		n	-	-	-	830
BOYS	BMI	*r*	1	0.825**	0.922**	0.943**
		n	542	542	537	542
	Waist Circumference	*r*	-	1	0.783**	0.804**
		n	-	542	537	542
	%BF	*r*	-	-	1	0.923**
		n	-	-	537	537
	BMI z-score	*r*	-	-	-	1
		n	-	-	-	542
GIRLS	BMI	*r*	1	0.772**	0.922**	0.944**
		n	288	288	277	288
	Waist Circumference	*r*	-	1	0.706**	0.732**
		n	-	288	277	288
	%BF	*r*	-	-	1	0.931**
		n	-	-	277	277
	BMI z-score	*r*	-	-	-	1
		n	-	-	-	288

** Correlation is significant at the 0.01 level (2-tailed)

Table 7.10 presents bivariate correlations investigating the association between anthropometrical variables, for the whole sample and separately for boys and girls. All of the anthropometrical methods of measurement were strongly positively correlated, for the whole group and split according to sex, with the value of Pearson's r ranging from 0.732 to 0.944, (all p<0.001).

7.2.4 Bivariate Relationships

7.2.4.1 Sex

Descriptive statistics for all anthropometrical variables are presented below. Differences according to sex were measured using Student's t-tests.

Significant differences between sexes were recorded for height and waist circumference, boys reporting a larger mean waist circumference but girls having a greater mean height.

Table 7.11 – Mean and 95% confidence intervals for Body Mass Index, BMI z-score, Height, Waist Circumference and Percentage Body Fat Split According to Sex

	BOYS		GIRLS		Significance
	N	**Mean (95% CI)**	**N**	**Mean (95% CI)**	**(2-tailed)**
BMI	542	19.9 (19.5-20.2)	288	20.1 (19.7-20.6)	0.409
BMI Z-Score	542	0.742 (0.6209-0.863)	288	0.5537 (0.394-0.7134)	0.068
Height (cm)	542	149.8 (149.1-150.5)	288	151.3 (149.1-150.5)	0.014*
WC (cm)	542	72.1 (71.3-73)	288	69.9 (68.8-71.1)	0.003**
%BF	537	30.8 (30.0-31.7)	277	32.0 (30.9-33.2)	0.095

* Significant difference observed between sexes (p<0.05); ** significant difference observed between sexes (p<0.01)

7.2.4.2 Age

Differences in anthropometrical variables according to age were also investigated. The vast majority of participants were either 11 or 12 years old, with only one 10 year old and five 13 year olds. Therefore, the study sample was split into two groups for this analysis, 11 and below, and 12 and above. Student's t-tests were applied to investigate significant differences. However, waist circumference failed the Levene's test, so a Mann-Whitney U test was used in this instance. A significant difference according to age was observed for height, 12 year olds being taller than their 11 year old counterparts.

Table 7.12 – Mean and 95% confidence intervals for Body Mass Index, BMI z-score, Height, Waist Circumference and Percentage Body Fat Split According to Age

	11 and Below		12 and Above		Significance
	N	**Mean**	**N**	**Mean**	**(2-tailed)**
BMI	362	19.8 (19.4-20.2)	468	20.1 (19.7-20.5)	0.285
BMI z-score	362	0.772 (0.635-0.909)	468	0.603 (0.468-0.738)	0.089
HEIGHT	364	149.1 (148.2-149.9)	472	151.3 (150.5-152.1)	<0.001*
Waist Circumference	362	71.5 (70.3-72.6)	468	71.3 (70.4-72.1)	0.823
%BF	358	30.8 (29.8-31.8)	456	31.6 (30.6-32.5)	0.253

* Significant difference observed between sexes ($p<0.001$)

7.2.4.3 Ethnicity

Significant differences in anthropometrical variables between ethnic groups were investigated using one-way ANOVA. However, waist circumference and BMI z-score failed Levene's test for equality of variance so a Kruskal-Wallis test was used to investigate differences between ethnic groups for both of these variables. Descriptive statistics and the results of ANOVA/Kruskal-Wallis tests are presented in table 7.13, below.

Parametric Bonferonni post-hoc tests were performed for BMI, height and %BF. Non-parametric Tamhane's post-hoc tests were performed for BMI z-score and WC. Significant differences between the BMI z-scores of South Asian and Black participants. Black participants were also significantly taller than their White and South Asian counterparts.

Table 7.13 - Mean and 95% confidence intervals for Body Mass Index, BMI z-score, Height, Waist Circumference and Percentage Body Fat According to Ethnicity

		N	Mean (95% C.I.)	Significance
BMI				**<u>0.026</u>**
	White	160	20.6 (19.9-21.3)	
	S. Asian	558	19.7 (19.3-20.0)	
	Black	103	20.5 (19.7-21.2)	
	Other	9	20.9 (18.1-23.8)	
BMI z-score				**<u>0.034</u>**
	White	160	0.847 (0.637-1.058)	
	S. Asian	558	0.566 (0.444-0.689)*	
	Black	103	0.960 (0.736-1.184)	
	Other	9	1.247 (0.387-2.108)	
Height				**<u><0.001</u>**
	White	161	150.2 (148.8-151.5)**	
	S. Asian	559	149.4 (148.7-150.1)**	
	Black	106	155.6 (154.1-157.2)	
	Other	10	150.1 (146.7-153.4)	
Waist Circumference				**<u>0.185</u>**
	White	160	71.1 (69.7-72.6)	
	S. Asian	558	71.7 (70.9-72.6)	
	Black	103	69.3 (67.7-70.9)	
	Other	9	75.6 (65.6-85.7)	
%BF				**<u>0.022</u>**
	White	154	32.7 (31.1-34.3)	
	S. Asian	548	30.5 (29.6-31.3)	
	Black	103	32.9 (31.2-34.7)	
	Other	9	32.6 (25.5-39.7)	

* Significant mean differences between S. Asian and Black groups ($p<0.05$); ** significant mean differences between Black group and White/S. Asian groups ($p<0.001$)

7.2.4.4 Socioeconomic Status

The association between socioeconomic status, as represented by a composite score, and anthropometrical variables was investigated through correlation. A table reporting the Pearson's correlation (r) coefficient between SES composite score and BMI, BMI z-score, WC and %BF is presented below (table 7.14). No significant associations were observed.

Table 7.14 – Pearson's Correlation between Socioeconomic Status and Anthropometrical Variables

	BMI	BMI z-score	WC	%BF
n	794	794	794	778
r	-0.010	-0.021	-0.023	0.015
Sig. (2-tailed)	0.785	0.56	0.519	0.674

7.2.4.5 School

All variables failed Levene's test for homogeneity of variance when split according to school (table 7.15). As a result, a non-parametric Kruskal-Wallis test was used to establish significant differences in anthropometrical variables between schools. Descriptive statistics for all schools are presented in table 7.15, below. Significant differences were observed for WC ($p<0.001$) and %BF ($p=0.01$). Tahmane's post-hoc tests showed significant differences between all schools for WC and between three schools for %BF. School 3 and school 7 reported significantly lower WC values, while school 6 reported a significantly lower mean value for %BF.

7.2.5 Summary of Bivariate Analysis

Bivariate analysis indicated that BMI was independently associated with BMI z-score, waist circumference, percentage body fat, height and the provision of step count data. Multivariate analysis would be conducted using stepwise regression, treating BMI as the dependent variable, and the five other listed variables as the independent variables (section 7.2.7). BMI, %BF, WC, height, ethnicity and provision of step data were individually associated with BMI Z-score. All of these variables would be included in a stepwise regression model, with BMI z-score treated as the dependent variable. Waist circumference was associated with BMI Z-score, BMI, height, gender, season, provision of step data, school and %BF. A stepwise regression model would be developed including all of these variables, with WC treated as the dependent variable. Percentage body fat was independently associated with BMI Z-score, provision of step data, height, BMI, school and WC. A stepwise regression model would be developed including these six variables, with %BF treated as the dependent variable.

Table 7.15 - Mean and 95% confidence intervals for Body Mass Index, BMI z-score, Height, Waist Circumference and Percentage Body Fat According to School

		N	Mean	Significance
BMI				0.131
	School 1	112	20.1 (19.3-20.9)	
	School 2	144	19.9 (19.1-20.6)	
	School 3	50	20.0 (19.1-20.9)	
	School 4	132	20.4 (19.6-21.2)	
	School 5	135	20.0 (19.3-20.7)	
	School 6	97	18.9 (18.2-19.6)	
	School 7	132	20.2 (19.5-20.9)	
	School 8	28	20.6 (19.4-21.9)	
BMI z-score				0.224
	School 1	112	0.797 (0.539-1.055)	
	School 2	144	0.400 (0.126-0.673)	
	School 3	50	0.975 (0.679-1.271)	
	School 4	132	0.769 (0.504-1.035)	
	School 5	135	0.716 (0.466-0.965)	
	School 6	97	0.543 (0.279-0.807)	
	School 7	132	0.659 (0.452-0.867)	
	School 8	28	1.007 (0.606-1.408)	
Waist Circumference				<0.001
	School 1	112	73.9 (71.8-76.0)	
	School 2	144	70.0 (68.6-71.3)	
	School 3	50	67.0 (65.7-68.3)	
	School 4	132	72.5 (70.7-74.2)	
	School 5	135	74.4 (72.5-76.2)	
	School 6	97	70.2 (68.5-72.0)	
	School 7	132	67.6 (65.9-69.4)	
	School 8	28	78.4 (75.4-81.4)	
%BF				0.010
	School 1	108	31.5 (29.8-33.3)	
	School 2	139	31.2 (29.2-33.1)	
	School 3	50	32.7 (30.5-34.8)	
	School 4	130	31.7 (29.6-33.8)	
	School 5	132	31.4 (29.8-33.1)	
	School 6	97	27.6 (25.9-29.4)	
	School 7	130	32.2 (30.8-33.7)	
	School 8	28	32.6 (29.6-35.5)	

7.2.6 Classification by Weight Status

Using current UK-specific guidelines, it was also possible to classify participants as normal, overweight or obese according to BMI (Cole et al., 2000), WC (McCarthy et al., 2001) and %BF (McCarthy et al., 2006). The results of these classifications are displayed in tables 7.16 and 7.17. Participants are grouped according to their ethnic and gender groups separately, and then together.

Table 7.16 - Classification of Participants (Ethnic and Gender Groups) by BMI, WC and %BF Weight Status

			BMI		WC		%BF	
			n	%	n	%	n	%
ETHNICITY:	WHITE	Underweight	5	3	1	1	2	1
		Normal	97	61	71	44	55	36
		Overweight	35	22	43	27	25	16
		Obese	23	14	45	28	72	47
	S. ASIAN	Underweight	13	2	3	1	19	4
		Normal	362	65	260	47	204	37
		Overweight	109	20	111	20	86	16
		Obese	74	13	184	33	239	44
	BLACK	Underweight	1	1	-	-	1	1
		Normal	65	63	49	48	29	28
		Overweight	24	23	40	39	22	21
		Obese	13	13	14	14	51	50
	OTHER	Normal	5	56	3	33	3	33
		Overweight	2	22	2	22	1	11
		Obese	2	22	9	100	5	56
SEX:	BOYS	Underweight	9	2	-	-	11	2
		Normal	346	64	258	48	179	33
		Overweight	103	19	133	25	86	16
		Obese	84	16	151	28	261	49
	GIRLS	Underweight	10	4	4	1	11	4
		Normal	183	64	126	44	112	40
		Overweight	67	23	64	22	48	17
		Obese	28	10	94	33	106	38

Using these classifications, amongst all boys 35%, 53% and 65% were overweight or obese according to BMI, WC and %BF, respectively. The respective results for girls were 33%, 55% and 55%. Figures were similar when participants were grouped according to ethnicity. For BMI, 36%, 33% and 36% of White, South Asian and Black participants, respectively, were overweight or obese. For waist circumference, 55%, 53% and 53% of White, South Asian and Black participants were overweight or obese. In terms of %BF, 63%, 71% and 67% of White, South Asian and Black participants were overweight or obese.

Table 7.17 – Classification of Participants (Sex * Ethnicity Groups) by BMI, WC and %BF Weight Status

			BMI		WC		%BF	
			n	%	n	%	n	%
BOYS:	**WHITE**	Underweight	1	1	-	-	-	-
		Normal	50	63	39	49	25	32
		Overweight	14	18	24	30	12	15
		Obese	14	18	16	20	42	53
	S. ASIAN	Underweight	7	2	-	-	10	3
		Normal	249	65	182	47	135	36
		Overweight	71	18	75	19	60	16
		Obese	58	15	128	33	175	46
	BLACK	Underweight	1	1	-	-	1	1
		Normal	44	62	35	49	18	25
		Overweight	16	23	31	44	13	18
		Obese	10	14	5	7	39	55
	OTHER	Normal	3	43	-	-	1	14
		Overweight	2	29	3	43	1	14
		Obese	2	29	2	29	5	71
GIRLS:	**WHITE**	Underweight	4	5	-	-	2	3
		Normal	47	58	32	40	30	40
		Overweight	21	26	19	23	13	17
		Obese	9	11	29	36	30	40
	S. ASIAN	Underweight	6	3	-	-	9	5
		Normal	113	65	78	45	69	41
		Overweight	38	22	36	21	26	15
		Obese	16	9	56	32	64	38
	BLACK	Normal	21	66	14	44	11	34
		Overweight	8	25	9	28	9	28
		Obese	3	9	9	28	12	38
	OTHER	Normal	2	100	2	100	2	100

7.2.7 Multivariate Analysis

Stepwise regression models were developed to evaluate the influence of multiple predictors on anthropometric variables. For BMI, the model included BMI z-score, waist circumference, percentage body fat, height and provision of step count data, all independently associated with BMI. The prediction model included four variables and was statistically significant, F (4, 809) = 2137.071, p<0.001 (table 7.18). Provision of step data was not a significant predictor of BMI. This model accounted for 91% of the variance of BMI (adjusted R^2 = 0.913).

Table 7.18 - Raw and standardised coefficients for bivariate regression and stepwise regression model for BMI

	Bivariate Regression			Stepwise Regression		
	B	Beta	Sig.	B	Beta	Sig.
BMI z-score	2.744	0.939	<0.001	1.577	0.529	<0.001
%BF	0.382	0.921	<0.001	0.141	0.341	<0.001
WC	0.332	0.798	<0.001	0.057	0.137	<0.001
Height	0.11	0.224	<0.001	-0.015	-0.032	0.004
Provision of Step Data	2.114	0.207	<0.001			

BMI, %BF, WC, height, ethnicity and provision of step data were all individually associated with BMI Z-score. Four of these predictors were included in a statistically significant stepwise regression model (F (4, 809) = 1953.226, p<0.001), height and provision of step count data being excluded as they were not deemed significant predictors in the model. Data were transformed using a log transformation, as they were not normally distributed, thus failing to meet the assumptions of regression. This model accounted for almost 91% of the variance in BMI z-score (adjusted R^2 = 0.906). Table 7.19 provides the bivariate and stepwise regression coefficients for BMI z-score.

Table 7.19 - Raw and standardised coefficients for bivariate regression and stepwise regression model for BMI Z-score

	Bivariate Regression			Stepwise Regression		
	B	Beta	Sig.	B	Beta	Sig.
BMI	0.321	0.939	<0.001	0.193	0.576	<0.001
%BF	0.128	0.919	<0.001	0.046	0.333	<0.001
WC	0.111	0.780	<0.001	0.010	0.074	<0.001
Ethnicity	0.041	0.017	0.618	0.063	0.027	0.012
Height	0.041	0.245	<0.001			
Provision of Step Data	0.689	0.189	<0.001			

Multivariate analysis of the combined influence of independent variables on WC was also performed using stepwise regression. Again, data was transformed using a log transformation as it was not normally distributed. A statistically significant model was developed ($F (7, 806) = 269.902$, $p<0.001$) using seven predictor variables, ordered according to their influence; BMI Z-score, season, BMI, height, gender, provision of step data and school (table 7.20). These variables accounted for almost 70% of the variance in WC (adjusted $R^2 = 0.698$). Percentage body fat was not a significant predictor of WC according to this model.

Table 7.20 - Raw and standardised coefficients for bivariate regression and stepwise regression model for WC

	Bivariate Regression			Stepwise Regression		
	B	Beta	Sig.	B	Beta	Sig.
BMI z-score	0.033	0.794	<0.001	0.010	0.234	<0.001
Season	0.022	0.183	<0.001	0.021	0.176	<0.001
BMI	0.011	0.796	<0.001	0.008	0.529	<0.001
Height	0.002	0.305	<0.001	0.001	0.154	<0.001
Gender	-0.013	-0.108	<0.001	-0.007	-0.054	0.012
Provision of Step Data	0.029	0.297	<0.001	0.007	0.048	0.018
School	-0.001	-0.047	<0.001	-0.001	-0.044	0.025
%BF	0.004	0.754	<0.001			

A stepwise regression model was developed to investigate the combined influence of BMI Z-score, provision of step data, height, BMI, school and WC on %BF (table 7.21). Again, a log transformation was conducted on the data. Only two of these predictors, BMI Z-score and provision of step data, were included in the statistically significant stepwise model ($F (2, 811) = 1660.912$, $p<0.001$). These two variables combined to account for over 80% of the variance in %BF (adjusted $R^2 = 0.803$).

Table 7.21 - Raw and standardised coefficients for bivariate regression and stepwise regression model for %BF

	Bivariate Regression			Stepwise Regression		
	B	Beta	Sig.	B	Beta	Sig.
BMI Z-score	0.105	0.896	<0.001	0.104	0.888	<0.001
Provision of Step Data	0.086	0.215	<0.001	0.016	0.041	0.010
Height	0.005	0.247	<0.001			
BMI	0.033	0.839	<0.001			
School	0.001	0.015	0.662			
WC	0.011	0.685	<0.001			

For BMI, BMI z-score, WC and %BF, all main effects and interactions were found to be non-significant.

CHAPTER 8 – RESULTS II

8.1 PHYSICAL ACTIVITY

8.1.1 Tests for Normality

Kolmogorov-Smirnov and Shapiro-Wilks tests of normality were run for total steps taken, total weekday steps taken and total weekend steps taken. In all but one test, the results suggested that the step count data was not normally distributed. However, these tests are less reliable when applied to larger sample sizes, so these results should be treated with caution as n > 600. Values for skewness and kurtosis were established for all variables. Skewness ranged from 00.352 to 0.545 while kurtosis ranged from 0.279 to 0.952 (see table 8.1). Boxplots for all three variables are also presented below (figure 8.1), and along with histograms (appendix 12) provided a visual representation of normality, distribution and skew. These graphs suggested that the distribution of step count data was relatively normal, enough so to analyse all step count data using parametric tests. For specific tests between subgroups, Levene's test for homogeneity of variance was used to check the assumption of equality of variance. Where variance was equal, parametric analysis was employed for the necessary post-hoc tests, and where variance was not equal, non-parametric analysis was employed.

Table 8.1 – Testing for Normality of Step Count Data

	Total Steps	Weekday	Weekend
N	681	680	400
Kolmogorov-Smirnov	0.200	0.032	0.027
Shapiro-Wilk	<0.001	0.001	0.003
Skewness	0.545	0.352	0.563
Kurtosis	0.952	0.435	0.279

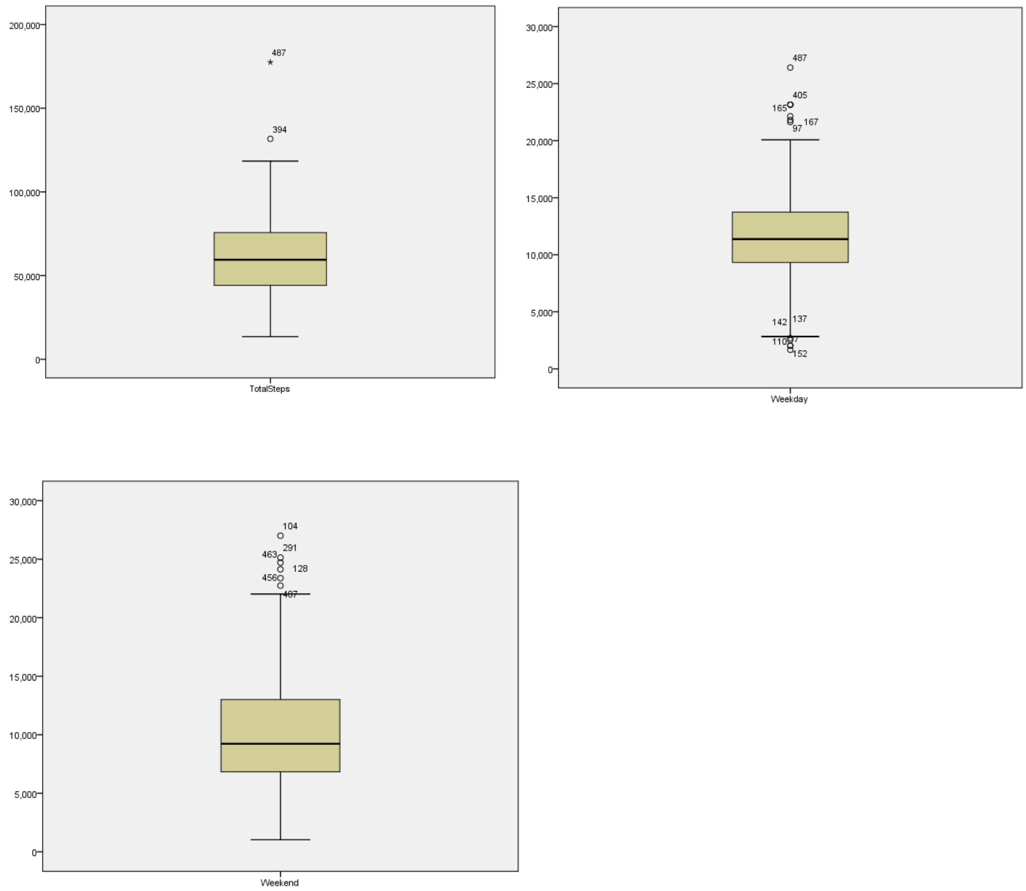


Figure 8.1 – Boxplots representing the distribution of Total Steps, Weekday Steps and Weekend Steps

8.1.2 Pedometer Reliability

Pedometer data collected from the walking test (100 steps) for the purpose of intra-instrument reliability is presented in table 8.2. This data was collected over the course of five days.

Table 8.2 – Mean, standard deviation, standard error of the mean, 95% confidence intervals, coefficient of variation and 95% limits of agreement for pedometer reliability step count data

	Ped 1	**Ped 2**	**Ped 3**	**Ped 4**
Mean (95% C.I.)	102 (100.2-103.8)	101.2 (99.2-103.2)	101.2 (98.4-104.0)	100.6 (97.4-103.8)
S.D	1.41	1.64	2.28	2.61
SEM	0.632	0.73	1.1	1.17
CV	1.39%	1.62%	2.25%	2.59%
95% LOA	-4.83-0.83	-4.49-2.09	-5.76-3.36	-5.82-4.62

Standard error of the mean values were low for all four pedometers, ranging from 0.632 to 1.1. These values, equating to approximately 1 step in a 100 step walking test, suggested that intra-instrument reliability was good. The coefficient of variation was also very low, ranging from 1.39% to 2.59%. Again, this suggested that intra-rater reliability was high for all four pedometers. The 95% limits of agreement were also calculated for each pedometer for the 100 step walking test. The range was similar in all cases, the largest range being -5.82 to 4.62. Combining these three measurements, gathered from 4 separate pedometers, suggested that intra-rater reliability was good for the New Lifestyle pedometer.

Reactivity: Reactivity was measured by comparing the variability between the first full day of step count data and the mean daily step counts for all participants. An intra-class correlation of 0.8 suggested that reactivity was not a concern and the first full day of activity data collected could be used in analysis.

Compliance: Compliance was measured by recording the number of children, in three separate classes, that wore their pedometers to form class over four days. From 70 participants, eight failed to wear their pedometer on the first day, 6 on the second and 7 on the third day, leading to a compliance rate of 90%

8.1.3 Pedometer Data Descriptive Statistics

8.1.3.1 Number of Days of Step Count Data Provided

The number of days of step count data provided varied from 2 days (the minimum number of days necessary for analysis) to 7 days (the maximum number of days of data stored in the pedometer). Figure 8.2 shows how many days of activity were provided by all participants.

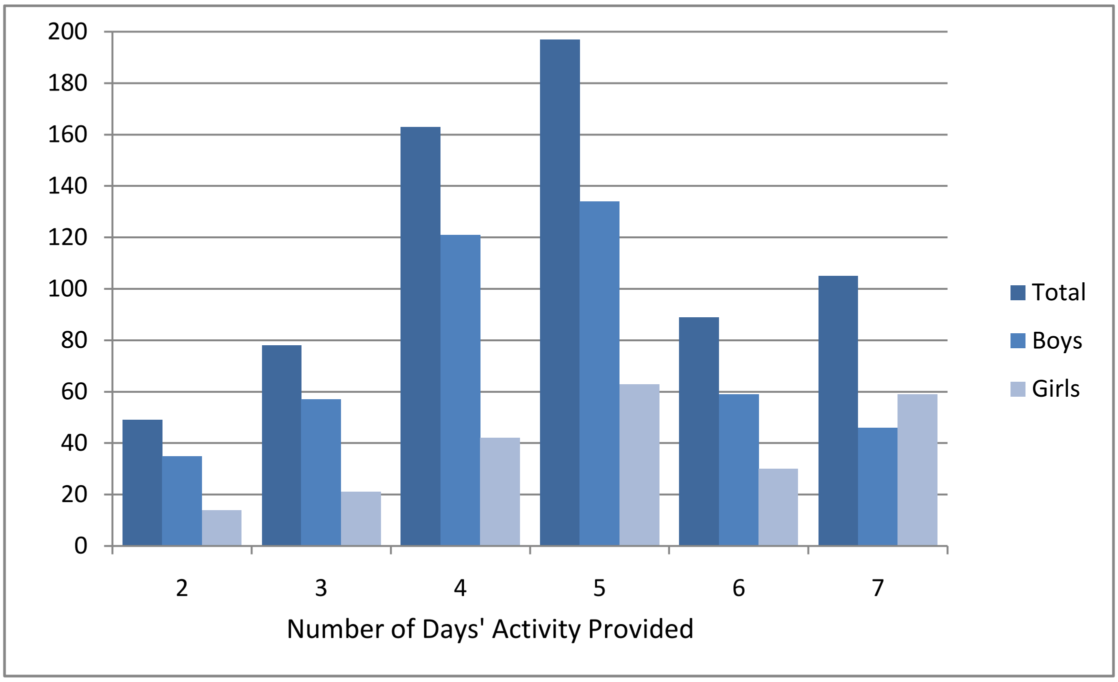


Figure 8.2 – Number of Days of Step Count Data Provided by All Participants

The majority of participants provided 4 (23.9%) or 5 days (28.9%) of step count data. The minimum number of days of data (2) was provided by 7.7% of boys and 6.1% of girls. However, 25.8% of girls provided a full 7 days of step count data, compared with 10.2% of boys. The mean daily step count totals of all participants are presented in table 8.3 according to the number of days of data that they provided.

Table 8.3 – Mean Daily Step Counts According to Number of Days of Activity Data Provided

	BOYS		GIRLS		TOTAL	
	N	**Mean (95% CI)**	**N**	**Mean (95% CI)**	**N**	**Mean (95% CI)**
2 Days	35	11356 (9635-13077)	14	9791 (9057-12525)	49	10909 (9491-12326)
3 Days	57	11387 (10408-12367)	21	8521 (6690-10352)	78	10616 (9721-11510)
4 Days	121	11097 (10475-11720)	42	10923 (9879-11967)	163	11052 (10523-11582)
5 Days	134	11944 (11352-12535)	63	10339 (9519-11160)	197	11431 (10943-11918)
6 Days	59	11659 (10906-12413)	30	9868 (8945-10790)	89	11055 (10450-11660)
7 Days	46	12090 (11081-13099)	59	9866 (9189-10543)	105	10840 (10228-11452)
All	452	11579 (11250-11908)	229	10062 (9641-10484)	681	11069 (10804-11334)

No significant differences between the number of days of activity data provided existed for either boys or girls.

8.1.3.2 Providers versus Non-Providers of Step Count Data

Of all those provided with a pedometer, 203 failed to provide any step count data. The demographic profile of this group is illustrated in table 8.4.

Table 8.4 – Sex and Ethnic Representation of all Participants Failing to Provide Step Count Data

	Total		White		South Asian		Black		Other	
	n	%	n	%	n	%	n	%	n	%
Boys	132	65	27	20	85	65	20	15	0	0
Girls	71	35	20	28	40	56	10	14	1	2
Total	203	100	47	23	125	61	30	15	1	1

Similar trends were visible for both sexes; South Asians accounted for the majority of those participants that failed to provide activity data (65% of boys, 56% of girls).

Differences in mean adiposity levels between those that did provide step count data and those that did not were investigated by pairwise comparison using t-tests, and the results are presented in table 8.5.

Table 8.5 – Mean (95% confidence intervals) for Body Mass Index, BMI z-score, Waist Circumference and Percentage Body Fat According to those Participants that Provided and Failed to Provide Step Count Data

		No P.A. Data		P.A. Data		Mean Difference	p-value
		N	**Mean (95% CI)**	**N**	**Mean (95% CI)**		
BMI	Boys	112	21.5 (20.7-22.2)	430	19.5 (19.1-19.9)	-2.0	<0.001
	Girls	61	22 (21-23)	227	19.6 (19.1-20.2)	-2.4	<0.001
BMIZ	Boys	112	1.245 (1.001-1.49)	430	0.611 (0.475-0.747)	-0.634	<0.001
	Girls	61	1.18 (0.897-1.463)	227	0.385 (0.203-0.568)	-0.794	<0.001
WAIST	Boys	112	76.1 (74.2-78)	430	71.1 (70.2-72)	-5.0	<0.001
	Girls	61	73.4 (70.8-76.1)	227	69 (67.8-70.2)	-4.4	0.001
%BF	Boys	111	35 (33.3-36.6)	426	29.7 (28.8-30.7)	-5.2	<0.001
	Girls	61	36.4 (34.3-38.6)	216	30.8 (29.5-32.1)	-5.6	<0.001

Significant differences were observed in all instances between those that provided step count data and those that failed to do so. BMI, BMI z-score, WC and %BF were all significantly greater amongst children that failed to provide step count data, regardless of sex.

8.1.3.3 Seasonal Changes

Differences in step count totals according to time of testing were also investigated. Data were split into two separate groups; data collected during daylight saving time (DST) and those collected outside of DST. Typically, daylight saving time refers to summer time, from the end of March to the end of October, resulting in days with more hours of sun. Differences in mean step count totals for both boys and girls are presented in the table 8.6.

Step count data was provided by 379 participants (300 boys, 79 girls) during DST, and 302 during the winter months. Student's t-tests indicated that there were no significant differences between those that provided physical activity data during DST and those that did not for mean daily steps, mean weekday daily steps or mean daily weekend day steps.

Table 8.6 – Mean and Standard Deviation Step Count Totals According to Time of Year

		BOYS			GIRLS		
		N	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**
Mean Steps	**Winter**	152	11462	3864	150	10074	3422
	DST	300	11640	3401	79	10039	2882
Weekday	**Winter**	152	11540	4408	149	10522	3665
	DST	300	11823	3738	79	10296	2846
Weekend	**Winter**	112	10930	4990	91	8274	4328
	DST	147	11029	4460	50	8671	4526

8.1.3.4 Weekday vs. Weekend Activity

Comparing mean daily weekday and weekend day activity (table 8.6), significant differences were observed in five of the six (sex * ethnicity) groups.

Both boys ($p<0.001$) and girls ($p<0.001$) took more steps during the weekdays than at the weekend. South Asian boys ($p=0.001$) were more active during the weekdays, although no difference was observed for the other ethnic groups. Both White and

South Asian girls took significantly more steps during the weekdays than at weekends (p<0.001).

Table 8.7 – Mean Differences between Weekday and Weekend Step Counts

		n	Mean Difference	Significance	Spearman's rho	
					rho	Significance
Boys	White	31	575 (-1825-2976)	0.628	0.046	0.807
	S. Asian	175	1218 (483-1952)	<0.001*	0.283	<0.001*
	Black	48	1538 (-239-3315)	0.088	0.339	0.019*
	Other	5	1150 (-5442-7741)	0.654	-0.564	0.322
Girls	White	42	2706 (1619-3792)	<0.001*	0.595	<0.001*
	S. Asian	86	1949 (911-2986)	<0.001*	0.308	0.004*
	Black	11	2739 (-255-5733)	0.069	0.409	0.212
	Other	0	-	-	-	-

* Significant difference observed between weekday and weekend step counts (p<0.05)

Both boys (p<0.001) and girls (p<0.001) took more steps during the weekdays than at the weekend. South Asian boys (p=0.001) were more active during the weekdays, although no difference was observed for the other ethnic groups. Both White and South Asian girls took significantly more steps during the weekdays than at weekends (p<0.001).

Of the 681 participants that provided physical activity data, 680 provided step count data for weekdays. Only 400 (58.8%) provided complete physical activity data for the weekend. A scatter-plot of the association between the two variables indicated that although the association was significant, a weak Pearson's correlation (r=0.314) was observed between weekday and weekend step counts (figure 8.3).

A Spearman rho correlation coefficient of 0.32 (p<0.001) was also calculated between mean daily weekday and weekend day steps. Similar results were found for both boys (ρ=0.240, p<0.001) and girls (ρ=0.388, p<0.001). This suggests that those participants that were active during the week were also active during the weekend and vice versa for inactive participants. Investigating specific sex*ethnicity subgroups, South Asian boys (ρ=0.283, p<0.001), Black boys (ρ=0.339, p=0.019), South Asian girls (ρ=0.308, p=0.004) and White girls (ρ=0.595, p<0.001) all reported a significant association between weekday and weekend steps. White boys reported no such association (see table 8.7).

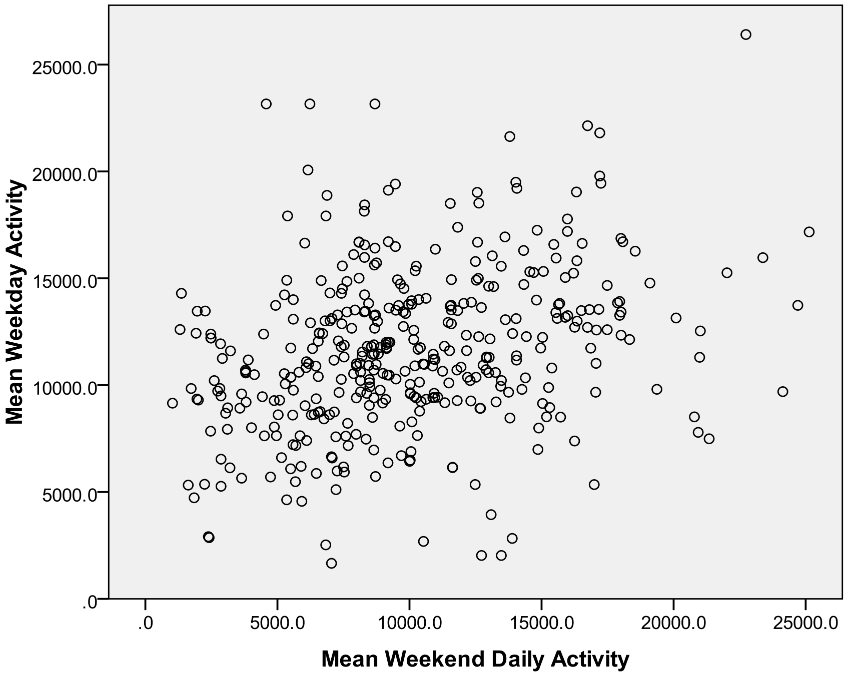


Figure 8.3 – Association between Mean Daily Weekday and Weekend Step Counts (r_s=0.314, p<0.001)

8.1.3.5 Activity Classification

Applying the step count guidelines developed by Tudor-Locke and colleagues (2004), it was possible to classify participants as “active” or “inactive”. The activity classification of all participants, grouped according to sex and ethnicity is presented in table 8.8.

Across all groups physical activity levels were generally very low, the majority in all cases being classified as inactive. Disregarding the Other group due to the small sample size, amongst boys, the South Asian group had the smallest percentage of active participants; only 15% of the group were deemed to be active, compared with 25% of the Black group. Girls performed slightly better, with the prevalence of active participants ranging from 25-30%. South Asian girls outperformed their male counterparts by a significant margin (30% versus 15%, p=0.001), doubling the percentage of active participants.

Table 8.8 – Activity Classification of Participants According to Current Step Count Guidelines (Tudor-Locke et al., 2004)

		TOTAL		White		S. Asian		Black		Other	
		n	%	n	%	n	%	n	%	n	%
Boys	Active*	75	17	11	18	47	15**	17	25	0	0
	Inactive	377	83	51	82	266	85	52	75	8	100
Girls	Active	64	28	16	25	42	30	6	27	0	0
	Inactive	165	72	49	75	98	70	16	73	2	100
TOTAL	Active	139	20	27	21	89	20	23	25	0	0
	Inactive	542	80	100	79	364	80	68	75	10	100

*Participants were classified as active if they scored a mean daily step count total greater than 12,000 or 15,000 steps for girls and boys, respectively; ** Significant difference between boys and girls (p=0.001)

8.1.4 Bivariate Relationships

8.1.4.1 Age

Physical activity, as determined by mean daily steps, mean weekday daily steps and mean weekend daily steps, is presented for both age groups, 11 and below and 12 and above, in table 8.9. No significant differences were observed according to pairwise comparison.

Table 8.9 – Mean and 95% Confidence Interval Step Counts According to Age

	Age group	n	Mean (95% C.I.)	Significance
Mean Daily Steps				**0.960**
	11 and below	330	11077 (10678-11475)	
	12 and above	351	11063 (10708-11418)	
Weekday Steps				**0.634**
	11 and below	330	11225 (10804-11645)	
	12 and above	350	11365 (10966-11764)	
Weekend Steps				**0.617**
	11 and below	170	10218 (9455-10981)	
	12 and above	230	9977 (9391-10564)	

8.1.4.2 Sex

Physical activity is presented according to sex in table 8.10. Significant differences between sexes, as measured by pairwise comparison using Student's t-test, were observed for all measures of physical activity.

Table 8.10 – Mean and Stand Deviation Step Counts According to Sex

		n	Mean	S.D.	Mean Difference	Significance
Mean Daily Steps					1518	<0.001*
	Boys	452	11580	3560		
	Girls	229	10062	3239		
Weekday Steps					1284	<0.001*
	Boys	452	11728	3973		
	Girls	228	10444	3399		
Weekend Steps					2571	<0.001*
	Boys	259	10986	4688		
	Girls	141	8415	4387		

* Significant difference observed between sexes ($p<0.001$)

Boys were significantly more active than girls in terms of mean daily steps ($p<0.001$), mean weekday daily steps ($p<0.001$) and mean weekend daily steps ($p<0.001$).

8.1.4.3 Ethnicity

Table 8.11 – Mean and 95% Confidence Interval Step Counts According to Ethnicity

		n	Mean (95%CI)	Significance
Mean Steps				**0.182**
	White	127	10644 (10005-11283)	
	S. Asian	453	11177 (10861-11494)	
	Black	91	11307 (10489-12126)	
	Other	10	9426 (7957-10895)	
Weekday				**0.213**
	White	127	10885 (10192-11578)	
	S. Asian	452	11409 (11069-11750)	
	Black	91	11519 (10584-12455)	
	Other	10	9443 (8074-10812)	
Weekend				**0.230**
	White	73	9185 (8139-10232)	
	S. Asian	262	10373 (9812-10933)	
	Black	59	10050 (8607-11494)	
	Other	6	8445 (3716-13174)	
	Total	400	10080 (9614-10546)	

Physical activity data is also presented according to ethnicity (see table 8.11). Comparing the four ethnic groups, as measured using one-way ANOVA, there were no significant differences observed between ethnic groups. The Black group recorded slightly more steps in all three instances. The Other group reported the lowest mean values in all instances, although the lack of any significant differences may have been affected by the reduced sample size of this group (n=10).

8.1.4.4 School

Differences in the physical activity levels between schools were also investigated. Because the data failed the Levene's test for each variable, a Kruskal-Wallis test (non-parametric) was used to test for significance by school. Mean daily steps, mean weekday steps and mean weekend steps all indicated significant differences in mean values between schools. A non-parametric post-hoc Tamhane's test was applied to check for significant differences between each school. The results of this test are displayed in table 8.12, stating mean differences in step counts between schools.

Table 8.12 Mean Step Count Differences Observed between Schools

		School 2	School 3	School 4	School 5	School 6	School 7	School 8
Mean Steps	School 1	-172.2	-1823.5	-3013.5*	-2031.8*	-604.9	-308.4	-440.9
	School 2	-	-1651.2	-2841.3*	-1859.6*	-432.7	-136.2	-268.7
	School 3	-	-	-1190.1	-208.3	1218.5	1515.0	1382.5
	School 4	-	-	-	981.7	2408.6*	2705.1*	2572.6*
	School 5	-	-	-	-	1426.9	1723.4*	1590.9
	School 6	-	-	-	-	-	296.5	164.0
	School 7	-	-	-	-	-	-	-132.5
	School 8	-	-	-	-	-	-	-
Weekday	School 1	-19.4	-1224.0	-2554.8*	-1365.2	-28.6	-233.7	17.9
	School 2	-	-1204.5	-2535.4*	-1345.7	-9.2	-214.3	37.4
	School 3	-	-	-1330.9	-141.2	1195.4	990.3	1241.9
	School 4	-	-	-	1189.7	2526.3*	2321.1*	2572.8*
	School 5	-	-	-	-	1336.6	1131.5	1383.1
	School 6	-	-	-	-	-	-205.1	46.5
	School 7	-	-	-	-	-	-	251.6
	School 8	-	-	-	-	-	-	-
Weekend	School 1	-1174.9	-2903.4	-4605.5*	-3832.3*	-3136.9	-412.2	-1805.6
	School 2	-	-1728.5	-3430.6*	-2657.4	-1962.0	762.8	-630.7
	School 3	-	-	-1702.1	-929.0	-233.5	2491.2	1097.8
	School 4	-	-	-	773.2	1468.6	4193.6*	2799.9
	School 5	-	-	-	-	695.4	3420.2*	2026.7
	School 6	-	-	-	-	-	2724.8	1331.3
	School 7	-	-	-	-	-	-	-1393.4
	School 8	-	-	-	-	-	-	-

* Significant difference observed between schools ($p<0.05$)

Significant differences in physical activity between schools occurred for mean daily steps, mean weekday daily steps and mean weekend daily steps. School 1 reported significantly less steps than schools 4 ($p<0.001$) and school 5 ($p=0.003$) for mean daily and weekend daily steps. Similarly, school 2 reported significantly less steps than school 4 ($p<0.001$) and school 5 ($p=0.018$) for mean daily steps. School 7 reported significantly fewer steps than school 4 ($p<0.001$) and school 5 ($p<0.001$) at the weekend. Schools 4 and 5 were the most active and school 1 the least active.

8.1.4.5 Socioeconomic Status

The association between physical activity and socioeconomic status, as determined by a composite SES score, was examined using correlation. The results of Pearson's correlation test between composite SES score and physical activity are presented in table 8.13.

Table 8.13 – Pearson's Correlation between Socioeconomic Status and Physical Activity

	Mean Steps	Weekday Steps	Weekend Steps
N	646	645	378
R	-0.001	0.001	0.082
Sig. (2-tailed)	0.990	0.982	0.111

Pearson's correlation coefficient indicated a very weak association between SES and all of mean steps ($r=-0.001$), mean weekday steps ($r=0.001$) and mean weekend steps ($r=0.082$). No significant correlations were found for any of these associations.

8.1.5 Summary of Bivariate Analysis

According to bivariate analysis, all three dependent physical activity variables (mean daily, mean weekday and mean weekend daily step counts) were independently associated with both gender and school. Multivariate analysis would be conducted by developing stepwise regression models, investigating the combined influence of the associated independent variables (gender and school) on each of the dependent variables.

8.1.6 Multivariate Analysis

Stepwise regression models were developed to investigate the combined influence of gender and school on all three step count variables (table 8.14). First, log transformations were conducted on all three sets of data as they were not normally distributed, thus failing to meet a required assumption of regression analysis. Raw and standardised regression coefficients are presented for both individual bivariate regressions and multiple stepwise regressions.

For mean daily steps, only gender was included in a statistically significant stepwise model (F (1, 679) = 27.73, p<0.001). This one predictor accounted for just 4% of the variance in daily step counts (adjusted R^2 = 0.038).

Table 8.14 - Raw and standardised coefficients for bivariate regression and stepwise regression model for Mean Daily Step Count, Steps per Weekday and Steps per Weekend Day

		Bivariate Regression			Stepwise Regression		
		B	Beta	Sig.	B	Beta	Sig.
Mean Steps	Gender	-0.064	-0.198	<0.001	-0.064	-0.198	<0.001
	School	0.003	0.044	0.253	-	-	-
Mean Weekday	Gender	-0.047	-0.132	0.001	-0.047	-0.132	0.001
	School	0.002	0.025	0.522	-	-	-
Mean Weekend	Gender	-0.136	-0.269	<0.001	-0.154	-0.303	<0.001
	School	0.011	0.099	0.049	0.018	0.163	0.001

A similar model was developed for mean weekday step counts, gender accounting for 16% of all variance in this statistically significant model (F (1, 678) = 11.987, p=0.001). The stepwise regression model for mean weekend daily step counts included both gender and school (F (1, 398) = 21.437, p<0.001). These two predictors combined to account for almost 10% (adjusted R^2 = 0.093) of the variance in mean weekend daily step counts.

8.2 ASSOCIATION BETWEEN ACTIVITY & ADIPOSITY

8.2.1 Bivariate Associations

The association between physical activity and BMI was examined using correlation. No significant associations were observed between BMI and any of mean daily, week-daily and weekend daily step counts (see table 8.15). Pearson's correlation values ranged from -0.075 to -0.025.

Table 8.15 – Pearson's Correlation between BMI and Physical Activity

	Pearson Correlation	Significance	N
Mean Steps	-0.037	0.341	657
Weekday	-0.025	0.526	656
Weekend	-0.075	0.138	387

Similarly, no significant associations were observed between step counts and BMI z-score (table 8.16), waist circumference (table 8.17) or percentage body fat (table 8.18). The weakness of these associations is evidenced in the results of the Pearson's correlations, ranging from -0.059 to -0.036 for BMI z-score, -0.084 to -0.07 for WC and -0.099 to -0.018 for %BF.

Table 8.16 – Pearson's Correlation between BMI z-score and Physical Activity

	Pearson Correlation	Significance	N
Mean Steps	-0.037	0.339	657
Weekday	-0.036	.0361	656
Weekend	-0.059	0.247	387

Table 8.17 – Pearson's Correlation between Waist Circumference and Physical Activity

	Pearson Correlation	Significance	N
Mean Steps	-0.074	0.057	657
Weekday	-0.070	0.073	656
Weekend	-0.084	0.098	387

Table 8.18 – Pearson's Correlation between Percentage Body Fat and Physical Activity

	Pearson Correlation	Significance	N
Mean Steps	-0.036	0.360	642
Weekday	-0.018	0.643	641
Weekend	-0.099	0.054	377

Furthermore, no significant associations were observed when the step count variables were split according to sex.

8.2.2 Step Counts by Weight Classification

Mean step count totals were also established according to participants' weight classification group. The step count data for boys and girls, defined as normal, overweight or obese according to BMI, WC and %BF, are presented in table 8.19.

Girls categorised as normal according to waist circumference cut-off guidelines were significantly more active than overweight girls (p=0.011), but not obese girls. No other method of adiposity level categorisation produced significant differences for either boys or girls.

Table 8.19 – Step Counts According to BMI, WC and %BF-determined Adiposity Classification

			BOYS		GIRLS	
			N	Mean (95% CI)	N	Mean (95% CI)
Mean Steps	BMI:	Normal	305	11571 (11176-11966)	163	10112 (9600-10625)
		Overweight	66	11945 (11070-12821)	47	9589 (8749-10428)
		Obese	59	11259 (10365-12153)	17	11060 (9240-12880)
		Total	430	11586 (11254-11918)	227	10075 (9650-10500)
Weekday		Normal	305	11709 (11271-12148)	162	10448 (9915-10981)
		Overweight	66	12091 (11089-13093)	47	9931 (9062-10800)
		Obese	59	11377 (10384-12371)	17	12035 (9971-14098)
		Total	430	11723 (11353-12092)	226	10460 (10013-10907)
Weekend		Normal	174	11246 (1054-611945)	102	8592 (7683-9501)
		Overweight	37	10497 (8795-12199)	27	7699 (6387-9012)
		Obese	35	10623 (9072-12174)	12	8519 (5631-11408)
		Total	246	11045 (10453-11636)	141	8415 (7684-9145)
Mean Steps	WC:	Normal	222	11926 (11429-12423)	110	10599* (9972-11226)
		Overweight	104	11001 (10385-11616)	52	9021 (8159-9883)
		Obese	102	11444 (10814-12075)	65	10031 (9266-10795)
		Total	428	11586 (11253-11920)	227	10075 (9650-10500)
Weekday		Normal	222	12104 (11546-12661)	109	10928** (10271-11586)
		Overweight	104	11204 (10517-11892)	52	9490 (8581-10398)
		Obese	102	11425 (10737-12113)	65	10450 (9629-11272)
		Total	428	11723 (11352-12095)	226	10460 (10013-10907)
Weekend		Normal	130	11288 (10460-12117)	68	8956 (7782-10129)
		Overweight	59	10983 (9866-12100)	34	6915 (5525-8306)
		Obese	55	10568 (9191-11945)	39	8779 (7611-9947)
		Total	244	11052 (10456-11648)	141	8415 (7684-9145)
Mean Steps	%BF:	Normal	167	11883 (11335-12430)	106	10047 (9373-10721)
		Overweight	74	11161 (10345-11977)	39	9852 (9067-10638)
		Obese	185	11460 (10963-11956)	71	10180 (9390-10970)
		Total	426	11574 (11240-11908)	216	10055 (9618-10493)
Weekday		Normal	167	12104 (11523-12686)	105	10301 (9611-10990)
		Overweight	74	11102 (10163-12041)	39	10356 (9483-11230)
		Obese	185	11573 (11005-12141)	71	10635 (9782-11488)
		Total	426	11700 (11328-12072)	215	10421 (9961-10881)
Weekend		Normal	97	11419 (10521-12317)	70	8885 (7680-10090)
		Overweight	35	11453 (9623-13283)	23	7713 (6479-8948)
		Obese	111	10570 (9683-11458)	41	8300 (7033-9567)
		Total	243	11036 (10441-11631)	134	8505 (7747-9262)

*Significant difference between normal and overweight for mean steps (p=0.011); **Significant difference between normal and overweight for weekday steps (p=0.036)

8.3 Summary of Findings

In total, 884 Year 7 students (11.6±0.5yrs) participated in the study. Of these, 657 provided a full set of pedometer, anthropometric and socio-demographic data. This represented 48% of all possible recruits at the 8 schools and 74% of all those recruited to participate. Boys accounted for 66% of all participants, while 20% of participants were White, 65% South Asian and 14% Black. Fifty-five percent received free school meals, 42% had no family car and 49% had neither parent in full-time employment.

Boys had a significantly larger waist circumference than girls, but girls were significantly taller than boys. Twelve year olds were also taller than 11 year olds. Black participants were significantly taller than White and South Asian participants, and they had a higher BMI-z score than South Asian participants. Significant anthropometric differences were observed between schools, specifically for waist circumference and percentage body fat. Amongst boys, 35%, 53% and 65% were overweight or obese according to BMI, WC and %BF, respectively. The respective results for girls were 33%, 55% and 55%.

Complete pedometer data was provided by 681 participants. Fifty-three percent of these participants provided four or five days of data, while 15% provided a full 7 days of data. Non-providers of activity data had higher levels of adiposity across all anthropometric variables. For all participants, activity levels were higher during the week than at the weekend. Weekday activity data was provided by 680 participants, while weekend activity data was only provided by 400 participants.

Boys recorded an average 11580±3560 per day while girls recorded 10062±3239 per day. Boys took significantly more steps than girls during the week and at the weekend. Significant differences in step counts were also reported between schools. Interestingly, these school-level differences were observed during the week and at the weekend. Amongst boys, 15% of South Asians were classified as active, compared with

18% of the White group and 25% of the Black group. Twenty-five percent, 30% and 27% of White, Black and South Asian girls, respectively, were classified as active.

The association between physical activity and all measures of adiposity was non-significant. Stepwise regression analysis provided further insight into the predictors of the dependent variables.

CHAPTER 9 – DISCUSSION

9.1 INTRODUCTION

This study provides the first objective findings regarding the physical activity patterns of children in Tower Hamlets. Particular detail is concentrated on activity data in the context of the cohort's ethnicity, socioeconomic status and adiposity levels. Physical activity data collection has been conducted in similar population samples before, although previous studies have not employed objective methods for the measurement of physical activity, nor have they concentrated specifically on Tower Hamlets' children. This study aimed to focus on the borough, given its uniquely diverse ethnic and socioeconomic profile. Adiposity levels were measured with a view to investigating the complex association between adiposity and physical activity.

Overall, the results regarding both activity and adiposity are of particular concern; high levels of adiposity and inactivity were reported for all participants in the cohort, regardless of ethnic or socioeconomic grouping. The majority of both boys and girls were inactive. Daily step count totals, as measured by pedometer, ranged from 11,325 to 11,876 for boys and 9,369 to 10,352 for girls. When compared against internationally recognised recommendations of 15,000 and 12,000 steps, respectively, it was established that only between 15 and 24% of boys reached the current recommended cut-off points. Girls performed slightly better, 25 to 30% reaching the recommended cut-off points.

Importantly, these figures were very similar across all three main ethnic groups in the study; White, South Asian and Black. The study hypothesises that ethnic minorities were at increased risk of inactivity, this was not the case. Similarly for adiposity levels, the other main health outcome recorded, no differences were observed according to ethnicity. The study also hypothesised that a lower socioeconomic status was associated with increased health risks in terms of both inactivity and obesity. No such associations were observed, although this may be explained by the homogeneity of the cohort with regard to SES.

Irrespective or ethnic or socioeconomic grouping, amongst all participants, adiposity levels were shown to be higher than current national recommendations (Saxena et al., 2004). However, different estimates of those overweight and obese were provided, depending on the measurement method applied. According to BMI-determined recommendations, adjusted for sex, between 61% and 69% of the cohort were classed as normal. Waist circumference-determined cut-offs suggested that only between 40 to 49% of the cohort were classed as normal, varying slightly across sex and ethnicity. However, percentage body fat-determined cut-off points that provided the highest estimation of adiposity, leading to just 26 to 38% of boys and 40 to 46% of girls being classified as normal.

Another primary research question addressed here regarded the nature of the association between pedometer-determined physical activity and adiposity. No association was observed, even accounting for potential confounding factors.

Important covariates of two key health outcomes, activity and adiposity, have been investigated in this study. The main covariates investigated were ethnicity and socioeconomic status, although the role of age, sex and school were also investigated. By conducting the research amongst an ethnically diverse and socioeconomically deprived study sample, the study adds new light to the nature and extent of health inequalities in such populations. This study also adds new information to the contentious issue of the nature of the association between physical activity and adiposity. It provides further insight into these issues through the use of an objective measure of activity and a number of measurement methods for adiposity, applied to a large study sample.

9.2 PHYSICAL ACTIVITY

9.2.1 Physical Activity Levels

The primary outcome measure of the current study was the physical activity levels of Year 7 children in Tower Hamlets. Gathered using pedometers, the data were presented both in terms of magnitude (step counts) and as a categorical variable, participants being classified as either active or inactive. Of a total study population of 884 participants, physical activity data was provided by 77% (n=681) participants. Boys outnumbered girls, accounting for 66% of the group.

As predicted, physical activity was significantly associated with sex; boys were consistently found to be more active than their female counterparts. On average, boys took 11580 steps per day, compared with 10062 steps for girls. A similar difference was also observed for both weekdays and weekend days, and was present across all three main ethnic groups on both weekdays and at weekends. It should be noted that while boys took more steps than girls, the prevalence of participants reaching their recommended daily step count recommendations was higher for girls than for boys.

The findings regarding the association between activity and sex are in agreement with the majority of studies investigating step counts amongst children (Duncan et al., 2006, Duncan et al., 2007c, Vincent et al., 2003), all of which reporting sex as a strong correlate of step counts. While the findings are presented in detail in chapters7 and 8, comparison with other activity studies, local, national and international, provides interesting context to better interpret the results.

National Comparisons: The most up-to-date national figures for the physical activity levels of children in the UK are gathered from the 2008 Health Survey for England (HSE), a nationwide study. Both questionnaire and accelerometer data were collected and presented according to sex and age. For interpretation of questionnaire results, to be defined as active, participants had to meet the Chief Medical Officer recommendations of 60 minutes exercise performed outside of school per day (CMO, 2004).

Table 9.1 – Comparison of UK Physical Activity Studies

	STUDY SAMPLE	Methods	Active*	Mean Steps
Current Study	N = 681, 11-12yrs, 81% non-white	Pedometer	17% boys, 28% girls	11,580 (boys), 10,062 (girls)
HSE '08	N = 6500, 2-15yrs	Questionnaire	32% boys, 24% girls / 11-12yr olds: 29% boys, 16-19% girls	n/a
HSE '08	N = 770, 4-15yrs	Accelerometer	33% boys, 21% girls / 11-15yr olds: 7% boys, 0% girls	n/a
RELACHS '08	N = 1880, 11-12yrs, 81% non-white	Questionnaire	51% inactive	n/a
CHASE '09	N = 2,071, 9-10yrs, 73% non-white	Accelerometer	64% whole sample, 54% S. Asians, 70% white	n/a
Duncan '07	N = 208, -11yrs, 13% non-white	Pedometer	29% boys, 47% girls	12,263 (boys), 11,748 (girls)

* Guidelines for classification varied across studies

The results of the questionnaire, self-reported for 13-15yr olds and by parents for 2-11yr olds, indicated that 32% of all boys and 24% of all girls were physically active. For more accurate comparisons, the results were also presented according to age. For boys, 29% of both 11 and 12yr olds were active, while for girls 16% of 11yr olds and 19% of 12yr old girls were active. Referring back to the current study, the trend is reversed, with only 17% of boys deemed active compared with 28% of girls. This may be explained by the fact that the recommendations employed in the current study, unlike those used in the 2008 HSE, are sex-specific. As a result, while both studies reported boys as being more active than girls, in the current study fewer boys achieved the recommended step count cut-off point as it is higher for boys than for girls (15,000 versus 12,000).

Objective physical activity data was also collected for the HSE, accelerometers being used by a subset of 770 4-15yr olds. In this instance, to be defined as active, children had to partake of at least 60 minutes of moderate to vigorous physical activity (MVPA) per day. Across all age groups, 33% of boys and 21% of girls were classed as active, findings closely related to those found in the questionnaire. However, when these data were broken down into two age brackets, 4-10yrs and 11-15yrs, interesting results were observed. For boys, 51% of the younger group were classed as active, compared with only 7% of the older group. For girls, 34% of 4-10yr olds were active and no 11-15yr olds met the recommended levels to be classed as physically active. Given the older age of the second group compared with the current study and the fact that children tend to become less active as they enter adolescence (Brodersen et al., 2007, Telama, 2009), lower levels of physical activity would be expected in the second group. Even so, there is a marked difference in the relative number of boys and girls reaching recommended activity levels between the two studies. With this in mind, the extremely low number of children in the current study classed as active may be as expected given national trends.

Although a common finding in similar studies involving a group with a wider age-range, age-related differences in activity levels were not observed in this sample. This could possibly be explained by the fact that the age range in the current study was just one school year. Differences between children are potentially related to year at school and less marked when the separate-aged children are in the same year.

Local Comparisons: At a local level, the Research with East London Adolescents; Community Health Survey (RELACHS) provides the best opportunity for comparison with other studies investigating physical activity. RELACHS was a large-scale study that included a sample of children from Tower Hamlets along with two neighbouring boroughs. Aiding comparisons between RELACHS and the current study, the ethnic and socioeconomic profiles of both cohorts were similar. Two studies in particular from RELACHS (Viner et al., 2008, Rothon et al., 2010) presented data regarding the physical activity levels amongst children from the boroughs of Newham, Hackney and Tower Hamlets. Both studies determined physical activity via questionnaire, asking children how many hours per week they participated in exercise that caused heavy breathing or sweating.

Rothon's study sampled 2789 children, 73% of whom were non-White and Viner's study sampled 1880 children, 27% of whom were Bangladeshi and a total of 81% were non-White British. Study participants ranged in age from 11 to 14 years, so along with their similar ethnic and geographical profile, they had a similar age profile to the children from the current study. Rothon presented activity as a scalar variable, ranging from 0 to 7 hours per week. Twelve percent of all participants completed zero hours of exercise, 51% completed up to 1hour of exercise, 22% completed 2 to 3 hours, 9% completed 4 to 6 hours and just 6% completed the maximum 7 hours or more per week.

Viner, using a definition developed by Booth and associates (2001), classified children as active if they exercised twice per week for an hour or more, and inactive if they failed to do so. Using these guidelines, 51% of the cohort was classed as inactive. Unfortunately, as neither of these studies treated physical activity as a primary research outcome, they did not provide more detailed analysis of the activity findings, investigating sex or ethnic differences. Comparisons with the current study are hindered by the fact that questionnaires can provide somewhat unreliable results (Sallis, 1991, Sirard and Pate, 2001) and the definitions of 'active' differed between studies. Even so, both Viner and Rothon's findings suggest physical inactivity was common amongst this cohort, the prevalence of inactivity being greater than 50%.

Comparisons are more readily made with another English study carried out by Michael Duncan and associates (2007c), as it also employed pedometers to measure physical activity. Duncan's study consisted of a slightly younger sample of 208 8-11yr olds from Central England. The study also used the same guidelines (Tudor-Locke et al., 2004) to categorise participants as either active or inactive. The step count data from the current study is presented with Duncan's study in table 9.2.

Table 9.2 Mean BMI & Step Counts (± standard deviation) for Duncan 07, Duncan 06*, Vincent 03** & the current study

		BMI	Steps/Day	Steps/Weekday	Steps/Weekend Day
BOYS	Duncan 07 (UK)	17.5 ± 2.9	12263 ± 3789	14111 ± 4163	10854 ± 4966
	Current Study	19.9 ± 4.1	11580 ± 3560	11728 ± 3973	10986 ± 4688
	Duncan 06 (NZ)	-	-	16132 ± 3864	12702 ± 5048
	Vincent (Swed)	-	15673–18346		
	Vincent (Aus)	-	13864–15023		
	Vincent (USA)	-	12554–13872		
GIRLS	Duncan 07 (UK)	18.5 ± 3.8	11748 ± 3310	13159 ± 3423	9922 ± 4061
	Current Study	20.1 ± 4.2	10062 ± 3239	10444 ± 3399	8414 ± 4387
	Duncan 06 (NZ)	-	-	14124 ± 3286	11158 ± 4309
	Vincent (Swed)	-	12041–14825		
	Vincent (Aus)	-	11221–12322		
	Vincent (USA)	-	10661–11383		

* Please note that the comparative studies refer to two different authors, Michael Duncan (UK) and J. Scott Duncan (NZ); ** Vincent only provided a range of values for mean step count according to age

Boys in Michael Duncan's study were more active over the course of the week, primarily as a result of a much greater mean weekday daily step count total compared with the current study. In fact, the current study reported a slightly higher level of activity for boys for weekend days. The girls included in Duncan's study were also more active than those in the current study, during the week and at weekends. The difference between mean weekday steps and mean weekend day steps was more marked in Duncan's study.

With higher mean step count values, Duncan and associates also reported increased compliance with the current step count guidelines for both boys (15000 steps) and girls (12000 steps).Almost 29% of boys in Duncan's study were classed as active, compared with just 17% in the current study. A greater difference was observed for girls classed as active, 47% in Duncan's study and 28% in the current study. Again, this may be partly explained by the younger age profile in Duncan's study. On average, children in the current study are two years older, 11.6yrs compared with 9.3yrs. As has been found in a number of studies investigating activity levels across this range of ages (Brodersen et al., 2007, Telama, 2009, DoH, 2008), children tend to become less active as they get older.

International Comparisons: Internationally, the current study can be compared with J. Scott Duncan and associates' study based in New Zealand (Duncan et al., 2006). The study involved 1074 children, aged 5 to 12yrs, with slightly more than 50% of the sample classed as European. Weekday and weekend mean daily activity for the whole group was higher for both boys and girls compared with the current study (table 9.2). Again, this may be in part explained by the younger age profile of the study sample. However, Duncan did provide mean step counts for different age brackets, although boys and girls values are presented together. A mean weekday step count total of 14801 (±4055) and weekend daily step count total of 10656 (±4653) for 11 to 12yr olds suggested that the sample of children from New Zealand was considerably more active than that in the current study.

J. Scott Duncan did note that his study sample seemed relatively active when compared with similar cohorts from other countries, particularly those reported by Vincent and associates (2003). In particular, Vincent and associates calculated pedometer-determined steps per day data for 6-12yr old children from Sweden, Australia and America. The study included 680 Swedish children (356 boys, 324 girls), 563 Australian children (278 boys, 285 girls) and 711 children from America (325 boys, 386 girls). Mean daily step count totals varied across countries and age groups; Sweden (boys = 15673–18346, girls = 12041–14825), Australia (boys = 13864–15023, girls = 11221–12322) and America (boys = 12554–13872, girls = 10661–11383). Unfortunately, the study did not provide more extensive detail regarding age-specific step count values or the variance of the data. However, the findings did not suggest the presence of a specific trend with regard to activity and increasing age.

The results presented by Vincent and J. Scott Duncan highlight the difference between activity levels of children in the UK and internationally. While the participants in Vincent's study had a younger age profile, when coupled with Duncan's results from New Zealand, they indicate that the cohort in the current sample is relatively inactive when compared internationally. Boys in Michael Duncan's UK study cohort also reported lower activity levels compared with international studies, although girls in that study reported higher levels of activity than their Australian and American counterparts in Vincent's study. Overall, comparing UK and international studies seems to confirm the findings from the recent government report on physical activity, 'Be Active, Be Healthy: a plan for getting the nation moving' (2009a) which, when compared to other developed countries, placed the UK outside of the top 20 in terms of physical activity.

Step Count Recommendations: The step count recommendations used in this study, 15,000 for boys and 12,000 for girls, were developed by Tudor-Locke (2004), one of the leading authorities on pedometry methods. The recommendations are widely used in pedometer studies, both in the UK and internationally (Belton et al., 2010, Duncan et al., 2006, Duncan et al., 2007c, Hands and Parker, 2008, Raustorp and Ludvigsson, 2007). This has both advantages and disadvantages. The widespread use of these recommendations is advantageous as it allows and encourages simple comparison of findings between studies, as has been achieved in the current study. Unlike those recommendations proposed by the CMO (2004), Tudor-Locke's recommendations are also gender-sensitive. Even so, the primary disadvantage of these commonly applied recommendations is that they may lack sensitivity, having been developed based on a specific cohort (see section 2.5). Tudor-Locke did warn that further cross-validation was warranted before the recommendations were universally accepted (see section 2.5.4).

While the guidelines are gender-sensitive, they fail to account for other variables that may be potential correlates of physical activity. For example, age is widely accepted as a key correlate of physical activity (Sallis et al., 2000). Young people become increasingly less active as they get older, and this should be reflected in the recommendations. Children are more active than adults and this is reflected in the fact that step count recommendations for adults are considerably lower, at 10,000 steps (Hatano, 1993). Other socio-demographic variables may also warrant consideration for future step count recommendations. Overall, the limitations associated with Tudor-Locke's guidelines are offset by the convenience of having universal recommended cut-off points, readily applicable to any study sample.

It is argued in some instances that guidelines should be sensitive to the ethnic profile of the cohort they are being applied to (Duncan et al., 2007a, Tudor-Locke et al., 2004). The exact nature of the association between activity and ethnicity is not fully understood (see section 9.2.2). Some large-scale studies have observed ethnic differences while others have failed to do so. However, universal agreement is lacking regarding this specific interaction; are ethnic minorities more or less active; which ethnic minorities are more or less susceptible to inactivity? Even if ethnicity-derived differences do exist, does this warrant the need for different step count recommendations for each ethnic group? It would seem more sensible to encourage those children from less active ethnic groups to partake of the same amount of activity as those from more active ethnic groups. Step count recommendations should provide a realistically attainable target. Adding to this discussion, the current study failed to report any association between step counts and ethnicity, further undermining the proposed argument that there is a need for ethnicity-specific step count recommendations.

Based on the findings from the current study and the application of Tudor-Locke's guidelines to the step count data, associated advantages and disadvantages were evident. The simple application of the step count cut-off points allowed for easy interpretation of pedometer data and reliable comparison with other studies in the UK and internationally. While there exists an argument for developing ethnicity-specific guidelines, the development of age-specific step count guidelines for children seems to be a more appropriate concern in terms of the refinement and development of widely applicable step count recommendations.

9.2.2 Physical Activity and Ethnicity

The primary aim of the current study was to investigate ethnic differences in the physical activity levels of children from Tower Hamlets. To do this, participants were categorised into one of three main ethnic groups; White, South Asian and Black. They accounted for 20%, 66% and 14% of the overall study population, respectively. The study initially aimed to investigate differences between White and South Asian children. However, given the large representation of Black participants in the study sample, they were included in analysis as a distinct separate group. A fourth 'Other' group was included for completeness. It consisted of children of East Asian and South American ethnic backgrounds. As such, the group was deemed too heterogeneous to draw any relevant conclusions from any significant findings from the 'Other' group. The ethnic profile of the study sample, 65% South Asian, 20% White and 14% Black enabled comparisons between these three groups.

Overall, no differences according to ethnicity were observed, suggesting that ethnicity was not a correlate of physical activity in this cohort. This observation was consistent for both boys and girls and for mean step count totals on both weekdays and weekends. These findings are in contrast to the findings from other studies in the UK comparing the activity levels of these two ethnic groups, many of which suggest that South Asian children are less physically active than their white counterparts (Brodersen et al., 2007, Owen et al., 2009).

Brodersen and associates (2007) investigated the role of ethnicity as a correlate of physical activity. The study sample included 4320 children from London schools. Measurements were recorded over a 5 year period, from the age of 11 to 16. Physical activity was assessed by asking participants on how many of the past 7 days they had carried out vigorous exercise that made them sweat and breathe hard, answers ranging from zero to seven days. As predicted, the author found that activity levels decreased as children got older. With respect to ethnicity, the study also found that Asian schoolchildren were less active and increasingly sedentary compared with their white counterparts; each week, Asian girls and boys exercised 0.45 days and 0.46 days less than their white counterparts. The author linked this finding to previous research that had indicated that South Asian adults are also less active than white adults (DoH, 2004) as well as the fact that they are more susceptible to the risk of type 2 diabetes and other metabolic disorders.

Bearing in mind the contention that South Asians are less active, the Child Heart Health Study in England (CHASE) also investigated differences in physical activity, concentrating specifically on ethnic differences (Owen et al., 2009). Although not in

Tower Hamlets, CHASE's sample did include a number of schools from London. The study population was also 73% non-white British, 24% of whom were South Asian. More importantly, the study employed accelerometers, an objective method to measure physical activity. In Owen's study, participants were classified as 'active' if they participated in at least 1 hour of moderate or vigorous physical activity (MVPA) every day of the week. Overall, 64% of the sample met these criteria and were classed as active. As expected, boys were more active than girls; 76% of boys were active and only 53% of girls were active. Looking at differences according to ethnicity, only 54% of the South Asian group were active, compared with 70% of the white English group. This difference was confirmed by comparing activity counts gathered by the accelerometers, white English children were found to be significantly more active than their South Asian counterparts.

The author suggested that the lower physical activity levels amongst the South Asian group may explain metabolic differences between the South Asian child population and their white counterparts, citing the former group's increased risk of type 2 diabetes and insulin resistance (Whincup et al., 2002, 2005, 2010). This hypothesis informed the design of the current study, but was ultimately called into question given the results failed to support the hypothesis. This may because the development of metabolic diseases and disorders is a complex process, affected by a wide variety of factors. Other factors such as adiposity, particularly central adiposity, are more prominent correlates in South Asians (Whincup et al., 2002) (see section 4.2.2). Other risk factors for metabolic diseases, including higher fasting glucose and insulin levels, raised C-reactive protein levels and lower HDL-cholesterol levels (Whincup et al., 2010), would also need to be investigated.

While physical inactivity may be a risk factor for the development of the metabolic disorders commonly associated with South Asians in the UK, the lack of evidence of an association between activity and ethnicity reported by Owen (2009) is understandable. It could potentially be explained by homogeneity within the cohort, similar to the current study. While ethnic differences were observed, the majority of other socio-demographic and environmental variables usually correlated with physical activity may have been common to both ethnic groups (Lindquist et al., 1999).

In general, children's activity patterns between approximately 8am to 4pm were informed by the school environment. In school, children's behaviour is monitored and controlled, thus ensuring that in theory, most children act in a similar fashion. Movement between classes, in class and, to a lesser extent, during lunch break, would have been similar; promoting equality in terms of how active they were. Outside school, this equality would not have existed. In theory children's commute to and from school may have varied significantly. However, in practise, Tower Hamlets is a small, densely populated area (see section 5.1.2), resulting in most children living close to their school, to the extent that commute distance may not have differed significantly between participants. Even if this were not the case, it would be speculative to assume that proximity to school is associated with ethnicity.

Overall, the relationship between physical activity and ethnicity is informed by many other variables, making it difficult for a direct association to be observed between activity and ethnicity (Sallis et al., 2000). In this regard, the hypothesis investigated by Owen and associates (2009) may have underestimated the complexity of the association between ethnicity, metabolic diseases and the risk factors that can cause them. The effect of socio-demographic and environmental variables not considered in the current study is discussed in section 9.5.

9.2.3 Physical Activity and Socioeconomic Status

The current study also aimed to investigate the role played by socioeconomic status as a correlate of the physical activity levels amongst children from Tower Hamlets. Along with measuring daily step counts, indicators of socioeconomic status were assessed via questionnaire. Overall, 55% received free school meals, 12% had both parents in employment, 49% had neither parent in employment and 42% had no family car. Looking at specific ethnic groups, these trends were consistent. The socioeconomic status results led to the assumption of a degree of homogeneity in the group for this variable.

Analysis suggested that for certain subgroups (South Asian boys, other boys), activity was associated with entitlement to free school meals, the primary indicator of socioeconomic status. Overall however, no significant associations were observed, suggesting that in the current study, none of the indicators of socioeconomic status are correlates of physical activity. Again, this may be explained by the level of homogeneity amongst children in Tower Hamlets. As previously discussed, it is one of the poorest boroughs in the country, as evidenced by the high level of child poverty in the area (NPI, 2010, 4in10, 2011). While there are two main distinct ethnic groups in the borough, potential activity differences between them may be negated by the fact that they share many socio-demographic variables.

Taylor and associates (2005) reported similar trends regarding socioeconomic indicators in a study from RELACHS. In that study, 48% were entitled to free school meals, 37% had no parent in employment and 30% reportedly had no family car. This suggests that this may be a particularly homogenous cohort in terms of socioeconomic status, there may not necessarily be a significant socioeconomic difference between those that do receive free school meals and those that do not. Certainly, it was not possible to view such a difference in terms of the physical activity levels of the current group.

This is in contrast with the 2008 Health Survey for England (DoH, 2008), which did observe an association between household earnings and activity, the prevalence of active children increasing with reduced household income. Comparing the highest and lowest quintiles for household income, the prevalence of active children increased from 25% to 36% for boys and 22% to 30% for girls. This may be explained by the fact that data was derived from the Health Survey for England, so the range between the highest and lowest socioeconomic quintiles would have been quite prominent, and from a large geographical area. Smaller studies, drawing participants from a more focussed geographical area, risk having a more homogeneous cohort. As a result, although a noticeable socioeconomic range may be observed, associated socio-demographic and environmental variables, and potential correlates of physical activity, might be common to all participants.

The effect that socioeconomic status plays as a determinant of physical activity is under-reported. Amongst adults, it has previously been found that those with a higher economic status tend to do more exercise and other recreational activities, but tend to do less activity-intensive work (Macintyre and Mutrie, 2004). Other UK-based studies have concluded that socioeconomically more disadvantaged children tend to be less active (Sproston and Mindell, 2006, Inchley et al., 2005). Given that the 2008 Health Survey for England reported an opposing trend, the role of socioeconomic status remains unclear.

These contrasting findings suggest that if an association is observed between physical activity and socioeconomic status, it may be an indirect one. Physical activity could potentially be more closely associated with other environmental factors related to a higher socioeconomic status; more green spaces, more parental support to do extra-curricular activities, money to fund those activities, improved local activity initiatives and resources. Therefore, even if these variables are significant correlates of physical activity, socioeconomically advantaged children in the current study may have fewer opportunities to avail of these correlates in a densely-populated, inner-city borough like Tower Hamlets.

9.2.4 Theoretical Basis for Physical Activity Differences

The hypothesis that ethnicity and socioeconomically derived differences in physical activity levels exist is based on the theoretical basis of social cognitive theory and reciprocal determinism. In a recently published book, Ward and associates argue that inactivity is affected by a number of psycho-social factors (Ward et al., 2007). While it should be intuitive for people to be physically active, primarily given the health benefits associated with activity, there are certain individual intentions and environmental barriers that influence one's motivation to be physically active. A number of theories influence activity behaviour, including social influences theory, self regulation theory and organisational changes theory. However, it is social cognitive theory that has the greatest effect.

Developed by the psychologist Albert Bandura, social cognitive theory led to the development of the concept of reciprocal determinism (Bandura, 1986). Reciprocal determinism proposes that a person's behaviour is influenced by and influences their personal attributes and their environment. This three-way interaction of behaviour, personal factors and environmental factors can be expressed by the triadic diagram shown in figure 9.1.

Applying this theory to an example involving physical activity, to understand or influence a person's physical activity, you must consider personal factors, such as self-efficacy, and environmental factors, such as friends' opinions. A person with high levels of self-efficacy will be less inclined to be de-motivated or influenced by friends' negative opinions regarding physical activity. As a result, they will be more physically active. Conversely, a person with low self-efficacy may be negatively influenced by their friends' views on physical activity, and will be less physically active themselves. This self-reflective element is central to the theory, thinking about one's thoughts and desires in the context of external behavioural factors and modifying physical activity behaviour accordingly (Biddle and Mutrie, 2008).

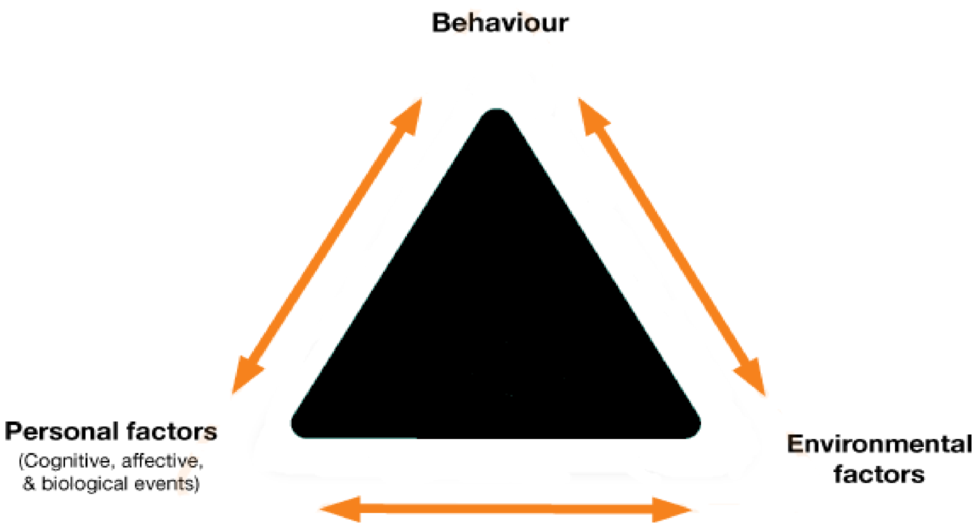


Figure 9.1 Graphical representation of Bandura's triadic reciprocal determinism

Applying this theory to ethnicity and socioeconomic status, both the environmental factors and personal factors that influence physical activity behaviour will be affected.

Cultural and environmental factors associated with ethnicity, and particularly ethnic minorities in East London, and socioeconomic deprivation can all act as potential correlates of physical activity. Examples of these include a lack of sports' facilities, the cost associated with engaging in sporting activities, cultural concepts of what physical activity is and how much is necessary. These correlates are discussed in detail in section 9.5.

9.3 PHYSICAL ACTIVITY AND ADIPOSITY

Another important aim of the current study was to investigate the association between physical activity and adiposity, as defined by BMI, waist circumference and percentage body fat. Analysis was performed on daily, weekday and weekend daily mean steps for boys and girls of different ethnicities, compared against BMI, BMI z-score, WC and %BF.

9.3.1 Trends in Adiposity

Black participants were significantly taller than White and South Asian participants, and they had a higher BMI-z score than South Asian participants. No other significant differences in adiposity levels between ethnic groups were observed. Classifying participants into weight categories based on BMI, WC and %BF, again no noticeable differences between ethnic groups were observed. However, previous research has highlighted ethnicity as an important correlate when measuring adiposity and fat distribution in children (McCarthy et al., 2001, McCarthy et al., 2006, Hirschler et al., 2005, Misra et al., 2005), suggesting it warrants consideration when developing adiposity cut-off points.

The findings from the current study are in contrast with those from a similar local sample observed as part of RELACHS (see section 5.2.1). Taylor and associates (2005) reported that prevalence of overweight and obesity, as derived from BMI, varied considerably according to ethnicity. Overall, the study reported very similar rates of overweight and obesity to the current study; 33% of boys and 39% of girls in Taylor's study were either overweight or obese. Looking at specific ethnic groups, 31% and 28% of Bangladeshi boys and girls, respectively, were overweight or obese in the study by Taylor, compared with 34% and 31% of South Asian boys and girls, respectively, in the current study. Taylor reported that 34% and 43% of white British boys and girls, respectively, were overweight or obese, compared with 35% and 36% of white boys and girls in the current study. The absence of a significant difference between these two ethnic groups in the current study may be due to the study being underpowered; BMI data was provided by 557 South Asian participants but only 158 white participants.

Waist circumference provides a measure of central adiposity (see section 4.2.3). It is widely proposed as a more sensitive measurement tool than BMI in ethnically diverse populations (Hubert et al., 2008, McCarthy et al., 2003, McCarthy et al., 2001, Cheng, 2005, Iwata et al., 2003). In fact, all three methods provided different indications of adiposity levels in this group. BMI predicted the healthiest adiposity profile, and percentage body fat the least healthy. For instance, 34% of boys were classed as overweight or obese according to BMI-determined definitions, compared to 52% according to WC and 65% according to %BF. Similarly for girls, 33% were classed as overweight or obese according to BMI-determined definitions, compared to 55% according to WC and 56% according to %BF.

The high prevalence of overweight and obesity according to percentage body fat, seemingly more sensitive to adiposity than WC, might be explained by the formula used to derived fat mass and thus, percentage body fat. Developed by Clasey and associates (2007, 2005), this formula has been successfully applied to an ethnically diverse UK population as part of the CHASE study (Nightingale et al., 2011). Given that both WC and %BF are proposed as more sensitive indicators of adiposity than BMI, particularly in ethnically diverse populations (see section 4.3.3.3), the prevalence of overweight and obesity according to these variables may be more representative of the true standing of this cohort than BMI. The BMI-derived rates of overweight and obesity are consistent with previous studies in the borough, indicating that approximately one third of children in Tower Hamlets are overweight or obese. These figures suggest that the rate of overweight and obesity in the borough is lower than national projections. Results from the 2009 Health Survey for England (DoH, 2009b) state that, nationally, 47% of boys (aged 2-15yrs) and 43% of girls are either overweight or obese. However, these national figures are lower than local projections based on both WC and BIA-derived %BF. The truth may actually be that WC and %BF provide a more accurate indication of adiposity levels in the borough's ethnically diverse population, both of which indicate that over half of all boys and girls in Tower Hamlets are overweight or obese. This would suggest that the rate of overweight and obesity in this cohort is greater than that of comparable studies and recent national projections.

9.3.2 Association Between Activity and Adiposity

No statistically significant associations were recorded between physical activity and any anthropometric variables. Similar results were observed when participants were grouped according to sex.

As previously discussed (see section 4.3), the nature of the association between activity and adiposity is contentious; many studies predict that the two variables are associated (Rowlands et al., 1999, Schofield et al., 2009, Vincent et al., 2003, Duncan et al., 2006, Hands and Parker, 2008), while other studies have failed to find any such association (Beets et al., 2008, Belton et al., 2010, Downs et al., 2008, Raustorp et al., 2006, Raustorp et al., 2004).

The current study aimed to add to the debate while also proposing the most accurate method for gauging adiposity in the current, ethnically diverse population. BMI is widely employed but its sensitivity as an indicator of adiposity has been highlighted as a potential limitation (Duncan et al., 2006). Bioelectrical impedance analysis-derived percentage body fat was measured to potentially provide the most sensitive indication of adiposity, and for comparison with other studies. The cohort was also grouped according to WC cut-off points for overweight and obesity, given waist circumference's sensitivity in measuring central adiposity. This form of adiposity is established as a risk factor for several negative health outcomes in childhood (Daniels et al., 1999). Waist circumference was the only anthropometric method to provide an association between adiposity and physical activity, thus potentially linking reduced step counts with pronounced central patterns of fat distribution. Ethnic variations could potentially have affected this relationship as without ethnicity-sensitive cut-off points, South Asian children could be misclassified (see 9.3.1).

Michael Duncan and associates (2007c) grouped participants according to their BMI-determined weight categories (normal, overweight and obese) and establishing the prevalence of active children in each group. The current study also presents similar data, although with the group split according to sex, and both studies are compared in figure 9.2.

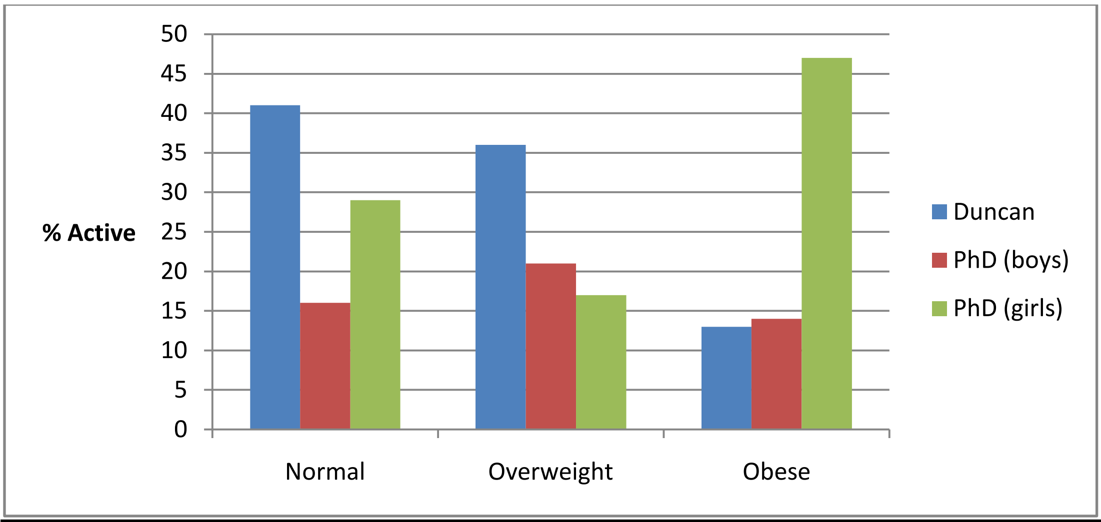


Figure 9.2 – Percentage of participants in Duncan 07 and the current study classified as 'active' according to BMI-determined weight status

Given that Duncan initially reported higher activity levels amongst the cohort, the prevalence of active children, as categorised by BMI, was also predominantly greater in Duncan's study. In only one instance participants from the current study outperform Duncan's study, for obese girls. As there were only 28 girls in this particular subgroup, assumptions cannot be made based on this one observation.

Another comparative point of interest between the two studies was the results of BMI testing. BMI levels were higher in the current study for both genders. The difference in age profile between studies is an important consideration here, as BMI varies considerably throughout childhood (Cole et al., 2000). The mean age of participants in Duncan's study cohort was approximately 2 years lower than the current study. According to the centile curves developed by Cole and adopted by the IOTF, both boys' and girls' BMI increases steadily from age 6, so a lower BMI profile in Duncan's study was expected. This problem could have been alleviated through the use of BMI z-score, given that it is adjusted for age. However, that data was not available from Duncan's study.

J. Scott Duncan and associates also reported the association between activity and adiposity in their New Zealand cohort (2006). Like the current study, this study also used three anthropometrical methods (BMI, WC and %BF) to determine adiposity levels in their study population. Only percentage body fat-determined adiposity was reportedly associated with physical activity, a high %BF (> 90th percentile) was related to a significantly lower step count on weekdays and weekends. The author suggested that only %BF was linked to activity because of certain limitations of BMI as an indicator of childhood adiposity. Duncan cited previous research that reported inter-individual variance in %BF at a given BMI among children from different ethnic backgrounds (Deurenberg et al., 2003). As a result, if BMI is be used as an indicator of adiposity, ethnicity-sensitive cut-off points for classifying overweight and obesity may be more appropriate for an ethnically diverse study sample, such as that used in the current study.

9.4 PATTERNS OF ACTIVITY

In the current study, participants were given a pedometer for a full week. Therefore, they could potentially provide 7 consecutive days of data, covering both weekdays (schooldays) and weekends. Of the 884 participants in the study, 77% (n=681) provided valid pedometer data for analysis. The socio-demographic profile of those that did not provide pedometer data was similar to that of the whole group, ruling out sex or ethnicity as correlates of the non-provision of activity data.

Interestingly, significant differences were found between the anthropometric variables of those that did provide pedometer data and those that did not. BMI ($p<0.001$), BMI z-score ($p<0.001$), WC ($p<0.001$ boys, $p=0.001$ girls) and %BF ($p<0.001$) were all significantly different between providers and non-providers of pedometer data, for both boys and girls. In all instances, non-providers of activity data recorded higher levels of each anthropometric variable. While the exact reason for this can only be speculated, it could suggest that overweight and obese children were less inclined to wear pedometers and provide activity data. They may have been conscious of the fact that they were relatively more overweight than their peers, and feared that this would be reflected in their activity levels if they provided pedometer data, thus choosing not to do so.

Of the 681 children that provided valid data for analysis, 680 provided weekday data and 400 (59%) provided weekend data. This raises concerns regarding compliance with the study protocol. Compliance was recorded in a small sample of the current cohort, and was found to be highly acceptable at 90%. However, it was only recorded during school on weekdays, not at the weekend. While the high level of compliance reported is reflected in the fact that 680 of 681 provided weekday activity, it does not provide any insight into weekend compliance. The contrast between compliance during the week and at the weekend is a limitation of the current study. This and other studies have reported a significant difference between weekday and weekend activity, underling the importance of gathering data from both periods of the week (see section 9.4.1).

Over half of participants provided either four or five days of activity data. The maximum number of days of data was provided by significantly more girls than boys, 26% compared with 10%. There was no difference between the mean daily step counts according to the number of days of data provided. This suggests that the number of days of physical activity data provided by participants was not associated with individual activity levels.

9.4.1 Weekday versus Weekend

Comparing mean values for daily steps, participants were consistently more active during the week than at the weekend. Notably, white boys were the only subgroup that did not achieve significantly more steps during the week than at the weekend. Previous studies applying different methods of activity measurement failed to find such a trend (Trost et al., 2000, Loucaides et al., 2003). However, similar trends were observed in other pedometer studies (Duncan et al., 2006, Duncan et al., 2007c). Although the magnitude of activity was considerably lower in the current study, all three studies reported that children were more active during the week than at weekends (table 9.2). Both Michael Duncan (2007c) ($p=0.001$) and J. Scott Duncan (2006) ($p<0.001$) reported significantly higher mean step counts during the week compared to the weekend. In the current study, mean weekday activity was significantly greater for South Asian and white girls ($p<0.001$) and South Asian boys ($p=0.002$).

Having observed a similar trend for their sample of New Zealand children, Duncan and associates (2006) suggested that it may be as a result of increased opportunity and motivation to partake in activities and exercise during the week compared with the weekend. This may also be true of the current study.

The importance of environmental factors in terms of their influence on physical activity is raised in section 9.5.2. The fundamental structure of a school day involves numerous activities that could increase daily step counts; commuting to and from school, walking between classes, lunch break (that may include exercise) and potentially physical education classes. Children also have the opportunity to partake in many different activities directly after school, particularly involvement with school sports teams. In contrast, children may be obliged to be more proactive and self-motivated to get involved with activities and sports that take place at the weekend. Without teachers and their school friends encouraging them to be involved in recreational activities, they could be less inclined to do so. This is supported by the findings from a recent UK study by Veitch and associates (2010) investigating changes in activity and sedentary behaviour patterns of children over the course of the week. The author cited the presence of children's friends as a significant correlate (OR=2.63) of increased physical activity.

Children could also potentially be less active at the weekend, viewing it as a time for less active behaviour. Children could be using their free time at the weekend as opportunity to engage in more relaxing sedentary activities, particularly television and video games. These particular activities do not warrant any ambulatory movement so would not increase a pedometer's step count. A study conducted by Rey-Lopez and associates (2010) compared children's patterns of sedentary behaviour between weekdays and weekends. The study reported that sedentary behaviour, including TV viewing, computer games, console games and internet use, was consistently greater at weekends compared with weekdays. The author noted that the observed trends in sedentary behaviour were consistent were the majority of previous research.

Another possible factor and potential limitation of the study design and pedometers in particular, is the concern that children were more compliant with the study's protocol during the school week than at the weekend. During the week, they may have had a specific routine that included wearing a school uniform and the pedometer was worn as part of that, putting on the pedometer may not have been ingrained into their weekend routine to the same extent. This is supported by the fact that of all 681 participants that provided pedometer data, only one participant failed to provide weekday data, compared with 281 (41%) participants that failed to provide any weekend data (see section 9.4). Furthermore, they may have been more inclined to wear the pedometer during the school week, to be seen to be complying with the protocol by teachers or the researcher. Such motivation would not have existed at the weekend.

In the current study, the fact that white boys were not significantly more active during the week stands in contrast to the rest of the group. Data analysis did not highlight a particular significant factor to explain this finding. It might possibly be explained by the presence of other socio-economic or environmental variables associated with white boys from Tower Hamlets (see section 9.5). The lower mean difference between weekday and weekend activity for white boys seems to be, compared to other boys, as a result of that groups low weekday activity as opposed to high weekend activity. White boys did not report significantly less steps during the week than their South Asians, but they did record a mean daily value that was 500 steps lower than that of the South Asian group.

Individual agreement between weekday and weekend activity was also measured in the current study, an observation that was not investigated in previous studies. A significant correlation was established ($p<0.001$), individual participants' activity levels on weekdays was proportional to their weekend activity. This implies that those that were most active during the week were also the most active at the weekend, and also children who were less active during the week were relatively less active at the weekend. This finding could be interpreted as suggesting that active children will always be active, irrespective of their surrounding environment. Similarly for inactive children, they will always fail to reach the recommended daily step count, regardless of whether they are in school or at home. This finding suggests that in this cohort, individual behavioural correlates play a more significant role influencing physical activity than communal environmental correlates.

9.4.2 Seasonal Effect

It was hypothesised that the time of year activity testing was conducted could affect the results. A child wearing a pedometer over a sustained period of time, during the summer and the winter, could potentially report significantly higher activity levels during the summer testing period due to the increased number of hours of daylight during the summer months, coupled with improved weather conditions; both providing a more favourable environment for outdoor activities. A recent review conducted by Carson and associates (2010) reported that 83% of the 35 studies included in the review suggest that a seasonal effect does influence physical activity. In a large-scale study investigating patterns of physical activity conducted in the UK, accelerometer data was analysed from 5,595 11yr olds (Riddoch et al., 2007). The results showed that children were less active in winter, recording 108 accelerometer counts per minute less than in the summer. Similar findings were reported in a

Scottish-based study by Fischer and associates (2005). Participants accumulated an extra 125 counts per minute in summer, confirming that seasonality plays a role in both physical activity and sedentary behaviour.

By classifying participants into two groups, those that supplied data during daylight saving time and those that supplied data outside of daylight saving time, seasonal changes in activity levels were examined in the current study. However, no differences were detected for either boys or girls, suggesting that this group of children did not spend more time outdoors being active during the summer than during the winter.

9.4.3 School Effect

Similar to a possible seasonal effect, a school effect may also be evident in physical activity levels. For boys, one school in particular was associated with significantly increased levels of activity both during the week and at the weekend. Throughout the week, the school produced significantly increased levels of activity to three other schools, (p=0.001-0.007). Looking specifically at the weekend, it only produced significantly increased activity levels compared to one of those schools (p=0.001). Significantly increased levels of activity for girls were also seen at this same school, compared to girls from three other schools (p=0.001-0.14). This difference was also observed for weekend activity although it was not as pronounced. Testing took place at this school during winter months, further undermining the theory that there may have been a summer/seasonal effect. The potential influence of adiposity as correlate was ruled out by the fact that mean anthropometric variables in this school did not differ significantly from the other schools in the study.

Other potential school level effects could have been included in the study to provide more insight into the role played by school in influencing physical activity (see section 6.3.4). Consideration was given to including information regarding school layout, catchment area and length of PE class. If any of these variables differed considerably between schools, it seems intuitive that it would affect physical activity levels. A longer commute (by foot) to school and between classes would lead to increased step counts, as would longer PE classes. Unfortunately, the investigation of this information was beyond the scope of the current study.

9.5 Other Potential Correlates of Physical Activity

Physical activity is a particularly complex variable, influenced by a wide variety of issues. The aims of the current study focused on socio-demographic (age, sex, ethnicity, socioeconomic status) and physiological correlates (adiposity) of physical activity. No environmental or psychological factors were considered, nor were a number of other socio-demographic and physiological correlates. Given the unique nature of Tower Hamlets, a number of other potentially influential factors do warrant consideration.

Many studies have been conducted exploring the multitude of factors that influence physical activity. In a systematic review, Sallis and associates (2000) identified the main correlates of physical activity in children. The review established that there were 40 variables commonly found to be correlated with childhood physical activity. These correlates have since been refined to three (Kohl and Hobbs, 1998) and then four broad categories (Lindquist et al., 1999); social/demographic, physiological/ developmental, environmental and psychological correlates. Particularly relevant to the current study are the socio-demographic factor of potential ethnicity-derived cultural differences in Tower Hamlets. These cultural differences (different to 'British culture') refer to the local South Asian and Muslim community and how this can affect physical activity.

9.5.1 Cultural Differences

In a study investigating barriers to the treatment of type II diabetes among British Bangladeshis, the author highlighted a number of cultural issues related to activity and exercise (Grace et al., 2008). Lay British Bangladeshi women reported that a desire to comply with cultural norms was a significant barrier to doing exercise, even though they were aware of the health benefits of physical activity. They claimed that in their culture, it lacked modesty for a woman to exercise in public and was thus inappropriate. They also stated that planned exercise, although popular in western society, was an alien concept to them, particularly so for first and second generation British Bangladeshis. This issue applied to both men and women.

Similar views were expressed in another study investigating barriers to physical activity amongst migrant South Asians in the UK (Patel et al., 2011). This study found that for women, spending time in activity was culturally inappropriate. It seemed that the role of the woman was to look after the home and children, proving a significant barrier to activity and exercise. The idea of exercising in the company of men was also deemed inappropriate. Other deterrents included a fear of the symptoms of exercise (breathlessness, rapid heart rate) and inappropriate clothing to exercise in. Similar to the findings made by Grace, this study found that spending time exercising was also seen as inappropriate for South Asian men. Traditionally, they have a very strong work ethic and when not working, they tend to spend their free time with family.

Physical activity data gathered from the 1999 and 2004 Health Survey for England confirmed that British South Asians are less active than their white counterparts (Williams et al., 2011). Inactivity was significantly more prevalent ($p<0.001$) amongst Bangladeshi/Pakistani adults (57%) compared to white British adults (28%). They were also three times more likely to die from coronary heart disease (CHD), the differences in activity levels explaining 41% of the excess CHD mortality risk. Referring back to Grace and Patel, both studies concluded that culturally sensitive interventions are warranted to improve physical activity levels amongst British South Asians.

Through a series of group discussions carried out in the mid-1990's, Rai and Finch (1997) conducted a qualitative analysis of the opinions of ethnic minorities in the UK regarding physical activity. The two main ethnic groups represented in the study were Black people and South Asian people. The study gathered information regarding attitudes and barriers to physical activity. Overall, no religious barriers to physical activity were reported, although certain cultural factors were reported as influencing people's views on physical activity.

From a conceptual point of view, people from these ethnic minorities had difficulty viewing physical activity as something separate, as opposed to integral, to daily functions. This was an opinion held predominantly by older people. Older people also viewed sweating as evidence that they were being active and a benefit of physical activity. They believed that sweating was proof that they were deriving health benefits, as it helped to release toxins from the body. Younger people recognised the social benefits associated with physical activity.

As highlighted in other studies, Rai and Finch also reported that many cultural barriers to physical activity do exist (1997). South Asian people emphasised the importance of the family unit, stating that spare time should be spent relaxing with family and children as opposed to doing physical activities. For both ethnic minorities, universal barriers included the need for a specific dress-code at sporting facilities, the lack of separate-sex facilities, excessive cost as well as the fear of racism. Rai and Finch noted that these barriers were similar to those highlighted by White people in previous research (HEA, 1992). South Asian people, particularly men, held the belief that they were very physically active and fit, seeing as they did not see any other members of their community partaking of physical activity.

Proposed steps to overcome barriers to physical activity were also explored by Rai and Finch (1997), participants agreeing that conceptual, motivational and structural issues need to be addressed. In terms of conceptual issues, the idea that spare time was for resting and not activity needed to be challenged and hopefully revised. The opinion, particularly amongst older people, that all sporting activities should be free, also needed reconsideration. From a motivational point of view, the social benefits and stress-relieving, as opposed to inducing, benefits of physical activity needed to be highlighted to people from ethnic minorities in the UK. Rai and Finch also found that from a structural point of view, barriers to physical activity, such as access, cost, location, opening hours needed to be addressed.

9.5.2 Environmental Correlates

Although not considered within the scope of the current study, environmental correlates can significantly affect physical activity levels (Lindquist et al., 1999). Time spent outdoors is consistently associated with increased physical activity (Sallis et al., 2000). Parks, green spaces and sports facilities provide a good opportunity for children to be active once outdoors. Specific environmental correlates of physical activity include access to and availability of green spaces.

Tower Hamlets is a densely populated area with a large proportion of high-rise accommodation (THC, 2011b) (see section 5.1.2). An Open Space Strategy presented by Tower Hamlets Council (THC, 2005) reported that although the borough contains 191 sites that are categorised as parks, 75% of these are actually less than the size of a football pitch. The paper also reported that the prevalence of green spaces in Tower Hamlets is inversely proportional to deprivation in the area. In particular, minorities (including Bangladeshis) living in socioeconomically deprived areas have the poorest access to green spaces.

A review of the influence of environmental attributes on physical activity by Davison and associates (2006) highlighted the role of green spaces. Physical activity was consistently positively correlated with proximity to green spaces. A larger systematic review conducted in 2010 also looked at the association between green spaces and physical activity (Lachowycz and Jones, 2011). Twenty (40%) of the 50 studies reviewed reported a positive association between activity and green spaces. However, the review included studies of both adults and children, and the studies came from many countries. Only six of 20 studies reporting a positive association focussed solely on children. Davison and associates (2006) noted that findings relating to adults cannot be applied to children. Children spend a significant proportion of their time in school and at play, and do not have the same access to cars that adults do.

The association between activity and environmental factors amongst children has been reported in UK-based studies. As part of the Health and Behaviour in Teenagers Study (HABITS) conducted by Brodersen and associates (2005), the affect of environmental factors on physical activity was investigated amongst 2578 boys and 1742 girls, aged between 11 and 12. The study reported that area deprivation was significantly associated with questionnaire-determined sedentary behaviour for both boys (p=0.004) and girls (p=0.001). Area deprivation was also associated with physical activity for girls (p=0.003). The study failed to show an association between physical activity or sedentary behaviour and investment in sports facilities or prevalence of sports pitches.

In a study measuring the effect of green spaces on health, Mitchell and associates (2007) found that results varied according to socioeconomic status. The availability of green spaces was linked to good health in areas of low socioeconomic status but not in areas of high socioeconomic status. The author suggested that this may potentially be explained by children with a higher socioeconomic status having their own gardens. As a result, they may be less reliant on public green spaces as a resource for outdoor activity. The possibility of this theory holding true would have considerable implications in Tower Hamlets. As previously mentioned, it is densely populated and has much high-rise accommodation. Although the information was not gathered in the current study, these conditions suggest that the prevalence of homes in the borough with gardens is low. As a result, local children would be particularly reliant on public green spaces as a facility for those children of low socioeconomic status to be active outdoors.

These environmental factors, although not recorded for the current study, are known correlates of physical activity and as such, may have influenced the results of the current study. Children in densely populated urban areas rely on access to green spaces to play sport and exercise. This need for public green spaces is further increased when children do not have gardens at home, depriving them of an environment to be active outdoors.

9.6 LIMITATIONS

In developing the design of this study, certain limitations were anticipated, necessary compromises that needed to be made. Further limitations became evident throughout the course of the study; recruitment, data collection, analysis and interpretation of findings.

As the primary outcome for this study, choosing the method of measurement of physical activity required serious consideration. Pedometers were chosen for their validity, ease of use, robustness and low cost, making them an ideal choice for large-scale studies involving children. They proved to be able to display all of these properties during the course of data collection, thus validating the choice to use them. However, certain compromises must be made when choosing any method of activity measurement and a number of limitations were experienced with pedometers. Potential limitations regarding reactivity and reliability were both recorded and not found to affect pedometer performance.

Compliance: The primary limitation of the pedometer is the fact that it provides a single reading for each day's activity, daily total step count. A single figure for daily total step count cannot be interpreted to draw any conclusions regarding patterns of activity over the course of the day. No distinction can be made between steps accumulated during school and those collected after school, data that would have proved very useful in the current study. Accelerometers are a feasible alternative, and have been used to good effect in previous studies to investigate patterns of activity over the full course of school days (Dale et al., 2000). They can provide minute-by-minute feedback which can be interpreted to establish when exactly activity was accumulated. This data can also be interpreted to provide more detailed information regarding physical activity intensity. The amount of low, moderate and vigorous intensity activity produced can be distinguished from one another. Although this extra information would have been very useful, the significantly increased cost of accelerometers compared with pedometers meant that they were not a feasible option in the current study.

Using pedometers, it is not possible to confidently confirm the accuracy of a single figure as a true representation of a full day of activity data collection. While a daily total value may represent a full day of activity, it could also potentially represent just a fraction of the day's activity. It is arbitrary, however, as long as the end value is between 1,000 and 30,000 steps. Aside from comparing returned pedometer data to these outliers, compliance with the study is difficult to ascertain. Parental involvement in the study could help account for possible compliance issues; having a figure of authority ensure the child wears their pedometer and also record when they did and did not wear the pedometer.

As previously discussed, only 400 of 681 children that provided activity data managed to provide data for the weekend. This calls into question the validity of pedometers outside the school environment. This study failed to ensure compliance during the week. Similar to the possible reasoning for reduced activity levels at the weekend, it may also be as a result of children not remembering to put their pedometers on with casual clothing. They may not have wanted to wear their pedometer at the weekend, associating it with school and as such, deeming it unnecessary when they were not in school. This is a potential limitation related to developing the study protocol in conjunction with schools, but was offset by the convenience of such a study design.

Recruitment: When designing this study, projections were made with a view to including as many as possible of the 15 schools and 2600 students in year 7 in the borough. However, recruitment proved difficult, particularly in terms of developing the initial lines of communication with the schools. Of the 15 schools approached to be involved, five of the 7 schools not included in the study did not respond at all. These schools were approached on a number of occasions (see section 6.2.1), initially through the head-teachers and then through the heads of PE. Emails explaining the nature of the study were followed up by phone calls to the heads of PE. Having exhausted all of these avenues, confident that the schools had been made aware of the study and what it entailed, and having had no response at all, it was accepted that these schools had no interest in being involved with the study. Although disappointing, it was expected and understandable that some schools would not be willing to participate in the study.

Individual recruitment was largely successful. The schools that did agree to participate were very supportive and helpful, improving the rate of recruitment significantly. In the final school however, the recruitment process differed to that of all of the previous occasions. At the school's request, the recruitment presentation was conducted by each class's form teachers, and collection was also followed up by teachers. The researcher was unable to provide any input, encouraging, incentivising and reminding children to participate in the study. As a result, a general feeling of disinterest led to a very poor recruitment rate at the final school.

It was initially hypothesised that the step count and anthropometric data provided by these participants, just 12% of those invited to participate, could be unrepresentative of the wider Year 7 population at that school, potentially introducing bias into the results. These participants could represent the more physically active and healthy students in the year. Initial descriptive and bivariate analysis dispelled this concern, these participants actually reported higher levels of overweight and obesity compared with other schools in the study. Similarly, both boys and girls reported lower step counts than the mean values for the complete study population. As a result, the hypothesis that these participants could provide an overly positive impression of that school's students was rejected. Coupled with the significant effort involved to recruit these participants, increasing the study sample, it was decided to include them in the results of the study.

Sample size: Issues regarding recruitment resulted in the final sample size being a limitation of the study. Prior to testing, the sample size required to observe a significant difference in the activity levels of the white and South Asian ethnic groups was calculated. A practically significant difference in physical activity levels between the two main ethnic groups was estimated as being 1,000 steps. This equates to a distance of approximately 0.5 miles or one tenth of a child’s daily activity. This represents a substantial amount of activity and a practically significant difference between the two ethnic groups. Based on the findings of previous studies investigating step count differences according to ethnicity (Duncan et al., 2006, Margham et al., 2008), a standard deviation of 4,000 steps was applied. Using a proposed test power of 90% and two-sided significance level of 5%, the sample size of each ethnic group was calculated as 336. Accounting for the increased prevalence of white children in the borough (51% white versus 37% South Asian), the revised sample sizes were 390 white participants and 284 South Asian participants.

In reality, physical activity data was provided by 127 White children, 121 Black children and 453 South Asian children (312 boys, 141 girls). Mean differences between ethnic groups, accounting for gender, were 256 steps for boys and 667 steps for girls. This resulted in effect size indexes of 0.07 and 0.2 for boys and girls, respectively. Given the sample size and effect size, the study achieved a power of 26% for boys and 64% for girls. Applying the mean differences and standard deviations observed, 1,237 boys and 310 girls would need to be tested from both ethnic groups for the study to achieve a power of 80%. A study with a power of 90% would require 1,713 boys and 429 girls in each ethnic group.

If this study was conducted again, the proposed sample size would have to be recalculated. Based again on a practically significant mean difference in step counts between ethnic groups of 1,000 and a standard deviation of 3,500 (as approximately observed in the current study) a study with 80% power would require 138 in each group while a study with 90% power would require 191 participants in each comparative group.

Statistical issues: Other potential statistical limitations of the study included chance, bias and confounding in analyses, issues of clustering of data, representativeness or generalisability of the data, multiple testing and potential type 1 & type 2 errors.

Type I and type II errors occur when an incorrect decision is made based on the results of objective statistical analysis. A type 1 error occurs when the null hypothesis is incorrectly rejected. Type II errors occur when the null hypothesis is incorrectly accepted (Portney and Watkins, 2000e)

A p-value of 0.05 was set to determine statistical significance during analysis. As a result, there still exists a 5% probability that the observed result (difference between two means) occurred by chance. A p-value of 0.01 was considered as the level of significance and this would have reduced the risk of type I errors occurring. However, a p-value of 0.05 was chosen, in keeping with the design of similar comparative studies. Also, the risk of a type I error was reduced by the lack of significant differences observed during analysis.

With respect to type I errors, it is also important to consider the number of statistical tests that are being conducted. If every test carries a 5% of a result occurring by chance, two tests carry a 10%, ten tests carry a 50% chance and conducting 20 tests leads to a 100% that a type I error will occur.

Type II errors can be affected by the power of the study. A non-significant outcome may mean that there is no difference between means, but it may also mean there is insufficient evidence (number/sample size) to observe a difference that does actually exist. This is particularly relevant to multivariate analysis.

Representativeness: An important feature of all research is the capacity for the findings from the study sample to be applied to a larger population with proportionately the same degree of diversity (Portney and Watkins, 2000c). This issue of representativeness of the study sample, and ultimately the generalisability of the results for all young schoolchildren in Tower Hamlets both need to be considered.

There are approximately 2,600 Year 7 students in Tower Hamlets, and 1385 in the eight schools involved in the study. A consecutive sampling approach was used, inviting every child who satisfied the inclusion criteria to participate in the study (Portney and Watkins, 2000d). However, not every eligible child was successfully recruited for the study. The total study sample, 884 participants, represents 64% of the total number of children in the schools involved and 34% of all children in all schools in the borough. The 657 participants providing full data equate to 47% of all Year 7 students in the schools recruited for the study, and 25% of all Year 7 students in Tower Hamlets. These figures lead to the question of how representative the data from the participants is for all Year 7 children in Tower Hamlets. Also, if this data represents 1 in 4 children in the wider population, can the findings from these data be applied to all children in the borough?

Census-based data claims that approximately 50% of schoolchildren in Tower Hamlets are South Asian and 35% are White (ONS, 2011). In this study, 66% of participants were South Asian and just 20% were White. A further 14% were Black. In terms of the representativeness of the socioeconomic profile of the study sample, 55% received free school meals, compared with 48% of all schoolchildren in the local area (Taylor et al., 2005). In the study, 42% of participants did not have a car and 49% did not have a parent in employment. According to best available data from previous studies in a similar population (Taylor et al., 2005), 30% of schoolchildren in the borough did not have a car and 37% did not have a parent in employment.

It is not possible to confidently predict if the socioeconomic and ethnic profile of the current study matches that of the borough, as detailed borough-specific data is not available. The census-based ethnic information refers to all school-aged children, not just the 11-12yr olds in Year 7. Also, the socioeconomic information gathered by Taylor and associates refers to children from Tower Hamlets, Newham and Hackney.

Based on the information available, the ethnic and socioeconomic profile of participants in the current study is similar to that of the whole borough, although the study sample has a greater representation of ethnic minorities and a slightly lower socioeconomic profile. This must be considered when interpreting the results of the study and drawing conclusions relevant to the wider borough population.

Other potential confounding factors: The influence of confounding factors on the study's outcome must be considered as a potential limitation. Physical activity is a very complex concept, influenced by a wide variety of determinants (Sallis et al., 2000). Similarly, adiposity is influenced by a wide variety of social, environmental, behavioural and physiological determinants too (Reidpath et al., 2002). Given the complexity of these health issues, it is impossible for a study of this size to control for all of these confounding factors. As a result, while some confounders of activity and adiposity were included in the study design, the vast majority were not. These uncontrolled determinants could potentially influence the results of the study.

Some of the socio-demographic variables that could be considered for inclusion in the study are family composition, marital status, religion, pupil educational attainment and special educational needs status. However, these variables are not directly related to the aims and objectives of this study. Given the limited resources of the study, primarily labour and time, to include more variables for collection and analysis would have reduced the focus on key determinants related to the aims of the study. As a result, seeing as they were outside the main scope of the study, it was decided not to include them. By increasing the number of variables included in the study, the level of background detail and critical evaluation of the current variables would have been diminished considerably.

With respect to the association between physical activity and adiposity, the main confounding factor affecting this relationship is energy/dietary intake. Energy intake is well established as a key determinant of adiposity, accounting for one whole side of the energy balance equation, the fundamental basis of weight management (Spiegelman and Flier, 2001). Energy intake is also a very complex variable, itself determined by a multitude of determinants. As a result, given the projected workload associated with controlling for energy intake as part of the current study, it was not deemed feasible to include it. Coupling this with the fact that energy intake was not directly related to the research questions, it was decided that energy intake was outside the scope of the current study.

9.7 CONCLUSION

9.7.1 Future Research

The findings from the current study and the limitations highlighted herein point towards a number of possible directions for future research. Although the activity data was objectively measured, more detailed information is needed to analyse the physical activity patterns of children. Testing involving accelerometry could allow future researchers not just to measure the magnitude of activity being performed on a daily basis, but also the specific behaviour that causes it. Future physical activity testing involving accelerometers could analyse a single school day in terms of a number of distinct periods; commute to school, time in classroom, lunch period, physical education class, commute home, evening at home. As it stands, differences between weekday and weekend activity cannot be accurately interpreted; does the increased activity during the week take place during school or after school? The use of accelerometers would ably inform important questions such as this.

Future research of child activity levels in Tower Hamlets would benefit from being broader in scope and longer in duration. Longitudinal research is required to observe changes in physical activity levels over a sustained period of time. It is widely accepted that children become less active as they get older, particularly during the transition from childhood to adolescence. This decline needs to be investigated further, particularly in terms of changes to associated variables and factors; when do children begin to become less active and how do potential correlates change at this time too? Questions regarding the causality of activity/inactivity could also be addressed in a longitudinal study.

The scope of potential correlates influencing activity that are investigated needs to be increased too. Physical activity is affected by a multitude of other variables; social, demographic, environmental, physiological and developmental. These need to be considered in an investigation of the association between activity and adiposity. Declining activity levels according to increased age may be explained by a range of reason; increased emphasis on academic pursuits, reduced influence/idolisation of figures in sport, organised sport being socially unacceptable, requirement to work or simply as a result of weight gain.

With respect to efforts to promote and improve current trends in physical activity levels in Tower Hamlets, future interventions and programmes need to be mindful of and specially adapted to the unique profile of the residents of the borough. Although this study failed to establish significant associations between either socioeconomic status or ethnicity and the health outcomes of activity and adiposity, cultural and environmental factors are established as important determinants of physical activity behaviour.

Rai and Finch (1997) emphasise the need for role models that children can relate to, to promote a healthy, physically active lifestyle. Black and South Asian role models are needed to inspire young people to be active, both famous sports personalities and 'ordinary people' that children can more easily connect with.

Qualitative research highlights the traditional views of the older South Asian community with regard to activity and exercise. These views need to be challenged through emphasis on the health-related benefits of physical activity. If this advice is not provided at the family/home environment, these benefits should be highlighted to children at school. The school environment also provides a positive opportunity to offer children the necessary access to physical activity facilities. Such facilities are not always readily available in socioeconomically deprived areas, further emphasising the role of the school in addressing this barrier to improved activity. The availability of school-based facilities also addresses the excessive costs associated with sporting facilities that affect children's motivation to pursue healthy activities in socioeconomically deprived areas.

Irrespective of the specific study design and outcome measures chosen, future research needs to gain the support of school head teachers, parents and ultimately the potential participants too. Doing this, ensuring all parties involved are motivated to participate in the study and persevere with the protocol, will lead to the collection of an increasing resource of reliable, accurate physical activity data. In turn, this will better inform and aid the development of future interventions and strategies aimed at improving child physical activity levels.

9.7.2 Summary

Tower Hamlets is a unique area with a local population defined by its low socioeconomic status, child poverty and ethnic diversity. Unfortunately, certain members of the borough's population are particularly susceptible to many negative health risks, even in childhood. From a young age, local children are at an increased risk to metabolic and cardiovascular health problems. The current study provides the first objective investigation in this cohort of their physical activity levels, an established health risk factor.

This study managed to gather important data from a sample of children representing both the South Asian and white populations in Tower Hamlets. The study highlights the extent of the problem of inactivity amongst children in Tower Hamlets; five in every six boys and almost three in every four girls fail to achieve current physical activity recommendations. This is coupled with rates of overweight and obesity higher than current national projections. A conservative estimate suggests that one third of all boys and girls are either overweight or obese. However, potentially more reliable projections put these figures at almost 60% for boys and 55% for girls.

Neither activity nor adiposity is affected solely by ethnicity, white and South Asian children displayed similarly poor results. A significant association was not observed between socioeconomic status and activity either. A direct association between physical activity and adiposity was not observed. The absence of significant observations here may be explained by both the homogeneity of the sample and the complexity of physical activity, influenced by a wide range of correlates. Future research investigating a broader range of correlates over a sustained period of time could provide further insight into the association between activity and adiposity. Regardless, interventions targeting the high prevalence of adiposity and inactivity in Tower Hamlets need to be developed, particularly given the predominant role that inactivity and obesity play in the development of serious health conditions, even at a young age. Continued high quality research of the determinants of activity and adiposity will help to further inform these issues and aid the development of effective interventions and strategies to improve the health of children in the borough.

REFERENCES

4IN10. 2011. *4 in 10: The End Child Poverty London Project - Tower Hamlets* [Online]. Available: http://www.endchildpoverty.org.uk/london/poverty-in-your-area/tower-hamlets-43/ [Accessed 17 Oct 2011].

ABEL, M. G., HANNON, J. C., EISENMAN, P. A., RANSDELL, L. B., PETT, M. & WILLIAMS, D. P. 2009. Waist circumference, pedometer placement and step count accuracy in youth. *Res Q Exerc Sport,* 80**,** 434-444.

AFGHANI, A., XIE, B., WISWELL, R. A., GONG, J., LI, Y. & ANDERSON, J. C. 2003. Bone mass of Asian adolescents in China: influence of physical activity and smoking. *Med Sci Sports Exerc,* 35**,** 720-9.

AFTAB, I., HANSON, J. & VAUGHAN, L. 2005. The spatial form of Bangladeshi community in London's East End. *Fifth International Space Syntax Symposium.* Delft, Netherlands.

AINSWORTH, B. E., HASKELL, W. L., LEON, A. S., JACOBS, D. R., MONTOYE, H. J., SALLIS, J. F. & PAFFENBARGER, R. S. 1993. Compendium of physical activities: classification of energy costs of human physical activities. *Med Sci Sports Exerc,* 25**,** 71-80.

AL-HAZZAA, H. M. 2007. Pedometer-determined physical activity among obese and non-obese 8- to 12-year-old Saudi schoolboys. *J Physiol Anthropol,* 26**,** 459-65.

AL-HAZZAA, H. M. & AL-RASHEEDI, A. A. 2007. Adiposity and physical activity levels among preschool children in Jeddah, Saudi Arabia. *Saudi Med J,* 28**,** 766-73.

ANDERSEN, L., HARRO, M., SARDINHA, L., FROBERG, K., EKELUND, U., BRAGE, S. & ANDERSEN, S. 2006. Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). *Lancet,* 368**,** 299-304.

ANDERSEN, R., CRESPO, C., BARTLETT, S., CHESKIN, L. & PRATT, M. 1998. Relationship of physical activity and television watching with body weight and level of fatness among children: results for the Third National Health and Nutrition Examination Survey. *JAMA,* 279**,** 938-42.

BAILEY, R. C., OLSON, J. & PEPPER, S. L. 1995. The level and tempo of children's physical activities: an observational study. *Med Sci Sports Exerc,* 27**,** 1033-41.

BANDURA, A. 1986. *Social foundations of thought and action: A social cognitive theory,* Englewood Cliffs, NJ, Prentice-Hall, Inc.

BARANOWSKI, J. 1984. Reliability and Validity of Self Report of Aerobic Activity: Family Health Project. *Res Q Exerc Sport,* 55**,** 309-317.

BARFIELD, J. P., ROWE, D. A. & MICHAEL, T. J. 2004. Interinstrument consistency of the Yamax Digi-Walker pedometer in elementary school-aged children. *Meas Phys Educ Exerc Sci,* 8**,** 109-116.

BAUMAN, A., PHONGSAVAN, P., SCHOEPPE, S. & OWEN, N. 2006. Physical activity measurement– a primer for health promotion. *Promot Educ,* 13**,** 92-103.

BEERTEMA, W., VAN HEZEWIJK, M., KESTER, A., FORGET, P. & VAN KREEL, B. 2000. Measurement of total body water in children using bioelectrical impedance: a comparison of several prediction equations. *J Pediatr Gastro Nutri,* 31.

BEETS, M., EILERT, A., PITETTI, K. & FOLEY, J. 2006. Student and parent self-report changes in physical activity behavior while wearing an unsealed pedometer. *Pediatr Exerc Sci,* 18**,** 492-9.

BEETS, M. W., LE MASURIER, G. C., BEIGHLE, A., ROWE, D. A., MORGAN, C. F., RUTHERFORD, J., WRIGHT, M., DARST, P. & PANGRAZI, R. 2008. Are current body mass index referenced pedometer step-count recommendations applicable to US youth? *J Phys Act Health,* 5**,** 665-674.

BEETS, M. W., PATTON, M. M. & EDWARDS, S. 2005. The accuracy of pedometer steps and time during walking in children. *Med Sci Sports Exerc,* 37**,** 513-20.

BELTON, S., BRADY, P., MEEGAN, S. & WOODS, C. 2010. Pedometer step count and BMI of Irish primary school children aged 6-9 years. *Prev Med,* 50**,** 189.

BERLIN, J. A. & COLDITZ, G. A. 1990. A meta-analysis of physical activity in the prevention of coronary heart disease. *Am J Epidemiol,* 132**,** 612-28.

BEUNEN, G. P., MALINA, R. M., RENSON, R., SIMONS, J., OSTYN, M. & LEFEVRE, J. 1992. Physical activity and growth, maturation and performance: a longitudinal study. *Med Sci Sports Exerc,* 24**,** 576-85.

BHOPAL, R., HAYES, L., WHITE, M., UNWIN, N., HARLAND, J., AYIS, S. & ALBERT, G. 2002. Ethnic and socio-economic inequalities in coronary heart disease, diabetes and risk factors in Europeans and South Asians. *J Public Health Med,* 24**,** 95-105.

BIDDLE, S. J. H. & MUTRIE, N. 2008. Introduction to correlates of physical activity. *Psychology of Physical Activity: Determinants, Well-Being and Interventions.* Routledge.

BOOTH, M. L., OKELY, A. D., CHEY, T. & BAUMAN, A. 2001. The reliability and validity of the physical activity questions in the WHO health behaviour in schoolchildren (HBSC) survey: a population study. *Br J Sports Med,* 35**,** 263-267.

BOUCHARD, C. & SHEPHARD, R. J. 1994. Physical activity fitness and health: the model and key concepts. *In:* BOUCHARD, C., SHEPHARD, R. J. & STEPHENS, T. (eds.) *Physical Activity, Fitness and Health: International Proceedings and Consensus Statement.* Champaign, Il.: Human Kinetics.

BOWLING, A. 2001. *Research methods in health. Investigating health and health services.,* Buckinghamshire, Open University Press.

BOWLING, A. 2005. Mode of questionnaire administration can have serious effects on data quality. *J Public Health,* 27**,** 281-91.

BRISSWALTER, J., COLLARDEU, M. & RENE, A. 2002. Effects of acute physical exercise characteristics on cognitive performance. *Sports Med,* 32**,** 555-66.

BRODERSEN, N. H., STEPTOE, A., BONIFACE, D. R. & WARDLE, J. 2007. Trends in physical activity and sedentary behaviour in adolescence: ethnic and socioeconomic differences. *Br J Sports Med,* 41**,** 140-4.

BRODERSEN, N. H., STEPTOE, A., WILLIAMSON, S. & WARDLE, J. 2005. Sociodemographic, developmental, environmental and psychological correlates of physical activity and sedentary behavior at age 11 to 12. *Ann Behav Med,* 29**,** 2-11.

BURDETTE, H., WHITAKER, R. & DANIELS, S. 2004. Parental report of outdoor playtime as a measure of physical activity in preschool-aged children. *Arch Pediatr Adolesc Med,* 158**,** 353-57.

BYRNE, N. M., HILLS, A. P., HUNTER, G. R., WEINSIER, R. L. & SCHUTZ, Y. 2005. Metabolic equivalent: one size does not fit all. *J Appl Physiol,* 99**,** 1112-9.

CARDON, G. & DE BOURDEAUDHUIJ, I. 2004. A pilot study comparing pedometer counts with reported physical activity in elementary schoolchildren. *Pediatr Exerc Sci,* 16**,** 355-67.

CARSON, V. & SPENCE, J. C. 2010. Seasonal variation in physical activity among children. *Pediatr Exerc Sci,* 22**,** 81-92.

CASPERSEN, C. J. 1989. Physical activity epidemiology: concepts, methods and applications to exercise science. *Ex Sport Sci Rev,* 17**,** 423-474.

CASPERSEN, C. J., POWELL, K. E. & CHRISTENSON, G. M. 1985. Physical Activity, Exercise and Physical Fitness: Definitions and Distinctions for Health-Related Research. *Public Health Rep,* 100**,** 126-131.

CATERINO, M. C. & POLAK, E. D. 1999. Effects of two types of activity on the performance of secod, third and fourth-grade students on a test of concentration. *Percep Mot Skills,* 89**,** 245-8.

CCR 2004. The Cochrane Collaborative Review Group on HIV Infection and AIDS Editorial Policy: Inclusion and Appraisal of Experimental and Non-experimental (Observational) Studies. The Cochrane Collaborative Review Group on HIV Infection and AIDS.

CDC 1998. National Health and Nutrition Examination Survey III - Body Measurements (Anthropometry). Rockville, MD.

CDC. 2000. *Overweight among US children and adolescents. National Health and Nutritional Survey* [Online]. http://www.cdc.gov/nchs/nhanes.htm. Available: http://www.cdc.gov/nchs/nhanes.htm [Accessed 11 March 2009].

CDC. 2011. *Diabetes - Successes and opportunities for population-based prevention and control at a glance 2011* [Online]. Available: http://www.cdc.gov/chronicdisease/resources/publications/AAG/ddt.htm [Accessed 05 Sept 2011].

CECP 2011. Child Poverty Map of the UK, Part 1: England. *Child Poverty Map of the UK.* Campaign to End Child Poverty.

CESI. 2011. *Child Poverty Toolkit: Tower Hamlets* [Online]. Centre for Economic and Social Inclusion. Available: http://www.childpovertytoolkit.org.uk/Data-Tools [Accessed 17 Oct 2011].

CHENG, T. O. 2005. Waist circumference is a better predictor of obesity-related health risk than body mass index in the Chinese including children. *South Med J,* 98**,** 124.

CHOWDHURY, T., GRACE, C. & PG, K. 2003. Preventing diabetes in South Asians. *BMJ,* 327**,** 1059-1060.

CLASEY, J., BRADLEY, K., BRADLEY, J. & LONG, D. 2007. A new BIA equation estimating the body composition of young children. *Obesity,* 15**,** A127.

CLASEY, J. L., BRADLEY, K. D., BRADLEY, J. W., LONG, D. E. & GRIFFITH, J. R. 2011. A new BIA equation estimating the body composition of young children. *Obesity,* 19**,** 1813-7.

CLEARY, J., DANIELLS, S., OKELY, A. D., BATTERHAM, M. & NICHOLLS, J. 2008. Predictive validity of four bioelectrical impedance equations in determining percent fat mass in overweight and obese children. *J Am Diet Assoc,* 108**,** 136-9.

CMO 2004. At Least Five a Week. Evidence on the impact of physical activity and its relationship to health. A report from the Chief Medical Officer. *In:* HEALTH, D. O. (ed.).

COLE, T. J. 1988. Fitting smoothed centile curves to reference data. *J Royal Stat Soc,* 151**,** 385-418.

COLE, T. J., BELLIZZI, M. C., FLEGAL, K. M. & DIETZ, W. H. 2000. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ,* 320**,** 1240-3.

COLE, T. J., FAITH, M. S., PIETROBELLI, A. & HEO, M. 2005. What is the best measure of adiposity change in growing children: BMI, BMI %, BMI z-score or BMI centile? *Eur J Clin Nutr,* 59**,** 419-425.

COLE, T. J., FREEMAN, J. V. & PREECE, M. A. 1995. Body mass index reference curves for the UK, 1990. *Arch Dis Child,* 73**,** 25-9.

CORDER, K., EKELUND, U., STEELE, R. M., WAREHAM, N. J. & BRAGE, S. 2008. Assessment of physical activity in youth. *J Appl Physiol,* 105**,** 977-987.

CPA 2006. Tackling Child Obesity - First Steps. Eighth Report of Session 2006-07. House of Commons, Committee of Public Accounts.

CRAIG, C. L., TUDOR-LOCKE, C., CRAGG, S. & CAMERON, C. 2010. Process and treatment of pedometer data collection for youth: The Canadian Physical Activity Levels Among Youth Study. *Med Sci Sports Exerc,* 42**,** 430-435.

CROUTER, S. E., SCHNEIDER, P. L. & BASSETT, D. R., JR. 2005. Spring-levered versus piezo-electric pedometer accuracy in overweight and obese adults. *Med Sci Sports Exerc,* 37**,** 1673-9.

CURRIE, C. E., ELTON, R. A., TODD, J. & PLATT, S. 1997. Indicators of socioeconomic status for adolescents: the WHO Health Behaviour in School-aged Children Survey. *Health Educ Res,* 12**,** 385-97.

DALE, D., CORBIN, B. C. & DALE, K. S. 2000. Restricting opportunities to be active during school recess: do children compensate by increasing physical activity levels after school? *Res Q Exerc Sport,* 71**,** 240-248.

DANIELS, S. R., MORRISON, J. A., SPRECHER, D. L., KHOURY, P. & KIMBALL, T. R. 1999. Association of body fat distribution and cardiovascular risk factors in children and adolescents. *Circulation,* 99**,** 541-5.

DAVISON, K. K. & LAWSON, C. T. 2006. Do attributes in the physical environment influence children's physical activity? A review of the literature. *Int J Behav Nutr Phys Act,* 3**,** 19.

DAVY, B. M., HARRELL, K., STEWART, J. & KING, D. S. 2004. body weight status, dietary habits and physical activity levels of middle school-aged children in rural Mississippi. *South Med J,* 97**,** 571-7.

DE VET, H., TERWEE, C. & BOUTER, L. 2003. Current challenges in clinimetrics. *J Clin Epidemiol,* 56**,** 1137-41.

DE VRIES, S. I., BAKKER, I., HOPMAN-ROCK, M., HIRASING, R. A. & VAN MECHELEN, W. 2006. Clinimetric review of motion sensors in children and adolescents. *J Clin Epidemiol,* 59**,** 670-80.

DEATON, C., FROELICHER, E. S., WU, L. H., HO, C., SHISHANI, K. & JAARSMA, T. 2011. The global burden of cardiovascular disease. *J Cardiovasc Nurs,* 26**,** S5-S14.

DELANEY, J. 1998. Role of energy expenditure in the development of pediatric obesity. *Am J Clin Nutr,* 68**,** 950-955.

DEURENBERG, P., KUSTERS, C. S. L. & SMIT, H. 1989. Assessment of body composition by bioelectrical impedance in children and young adults is strongly age-dependent. *Eur J Clin Nutr,* 44**,** 261-268.

DEURENBERG, P., VAN DER KOOY, K., LEENAN, R., WESTSTRATE, J. A. & SEIDELL, J. C. 1991. Sex and age specifc prediction formulas for estimating body composition from bioelectrical impedance: a cross validation study. *Int J Obes Relat Metab Disord,* 15**,** 17-25.

DEURENBERG, P. M., DEURENBERG-YAP, M., FOO, L., SCHMIDT, G. & WANG, J. 2003. Differences in body composition between Singapore, Chinese, Beijing Chinese and Dutch children. *Eur J Clin Nutr,* 57**,** 405-9.

DIRECTGOV. 2011. *Nutrition and School Lunches* [Online]. Available: http://www.direct.gov.uk/en/Parents/Schoolslearninganddevelopment/SchoolLife/DG_4016089 [Accessed 11 Oct 2011].

DOH 1996. Strategy statement on physical activity. London: Deparment of Health.

DOH 2004. Health Survey for England 2004: Health of Ethnic Minorities. London: Department of Health.

DOH 2008. Health Survey for England 2008. London: Department of Health.

DOH 2009a. Be Active, Be Healthy: a plan for getting the nation moving. London: Department of Health.

DOH 2009b. Health Survey for England 2009. London: Department of Health.

DOWNS, S. M., MARSHALL, D., NG, C. & WILLOWS, N. D. 2008. Central adiposity and associated lifestyle factors in Cree children. *Appl Physiol Nutr Metab,* 33**,** 476-82.

DUGDILL, L., STRATTON, G. & WATSON, P. 2009. Developing the evidence base for physical activity interventions. *In:* DUGDILL, L., CRONE, D. & MURPHY, R. (eds.) *Physical Activity and Health Promotion: Evidence Based Approaches to Practice.* Oxford, UK: Wiley-Blackwell.

DUNCAN, J. S., SCHOFIELD, G. & DUNCAN, E. K. 2006. Pedometer-determined physical activity and body composition in New Zealand children. *Med Sci Sports Exerc,* 38**,** 1402-9.

DUNCAN, J. S., SCHOFIELD, G. & DUNCAN, E. K. 2007a. Step count recommendations for children based on body fat. *Prev Med,* 44**,** 42-4.

DUNCAN, J. S., SCHOFIELD, G., DUNCAN, E. K. & HINCKSON, E. A. 2007b. Effects of age, walking speed, and body composition on pedometer accuracy in children. *Res Q Exerc Sport,* 78**,** 420-8.

DUNCAN, J. S., SCHOFIELD, G., DUNCAN, E. K. & RUSH, E. C. 2008a. Risk factors for excess body fatness in New Zealand children. *Asia Pacific J Clin Nutr,* 17**,** 138-47.

DUNCAN, M. J., AL-NAKEEB, Y. & WOODFIELD, L. 2008b. Relationship between body esteem, objectively measured physical activity and anthropometry in children. *In:* SIMMONS, M. P. & FOSTER, L. A. (eds.) *Sport and Exercise Psychology Research Advances.* Hauppauge, NY, US: Nova Biomedical Books.

DUNCAN, M. J., AL-NAKEEB, Y., WOODFIELD, L. & LYONS, M. 2007c. Pedometer determined physical activity levels in primary school children from central England. *Prev Med,* 44**,** 416-20.

DWYER, T., COONAN, W. E., LEITCH, D. R., HETZEL, B. S. & BAGHURST, R. A. 1983. An investigation of the effects of daily physical activity on the health of primary students in South Australia. *Int J Epidemiol,* 12**,** 308-313.

EKELUND, U. 2004. *Methods to Measure Physical Activity* [Online]. Available: http://www.dasfas.dk/2004/Ulf_Ekelund_Symposium_300804.pdf [Accessed 20 Sept 2011].

EKELUND, U., AMAN, J., YNGVE, A., RENMAN, C., WESTERTERP, K. & SJOSTROM, M. 2002. Physical activity but not energy expenditure is reduced in obese adolescents: a case-control study. *Am J Clin Nutr,* 76**,** 935-41.

ERSELCAN, T., CANDAN, F., SARUHAN, S. & AYCA, T. 2000. Comparison of body composition analysis methods in clinical routine. *Ann Nutr Metab,* 44**,** 243-8.

ESTON, R. G., ROWLANDS, A. V. & INGLEDEW, D. K. 1998. Validity of heart rate, pedometry, and accelerometry for predicting the energy cost of children's activities. *J Appl Physiol,* 84**,** 362-71.

FINN, K. J. & SPECKER, B. 2000. Comparison of Actiwatch activity monitor and Children’s Activity Rating Scale in children. *Med Sci Sports Exerc,* 32**,** 1794-7.

FISCHER, A., REILLY, J. J., MONTGOMERY, C., KELLY, L., WILLIAMSON, A., JACKSON, D. M., PATON, J. Y. & GRANT, S. 2005. Seasonality in physical activity and sedentary behavior in young children. *Pediatr Exerc Sci,* 17**,** 31-40.

FOLEY, L., MADDISON, R., OLDS, T. & RIDLEY, K. 2012. Self-report use-of-time tools for the assessment of physical activity and sedentary behaviour in young people: systematic review. *Obes Rev,* 13**,** 711-22.

FOX, K. R. 2000. The effects of exercise on self-perceptions and self-esteem. *In:* BIDDLE, S. J. H., FOX, K. R. & BOUTCHER, S. H. (eds.) *Physical Activity and Psychological Well-Being.* London: Routledge.

FREEDMAN, D. S., SRINIVASAN, S. R., VALDEZ, R. A., WILLIAMSON, D. F. & BERENSON, G. S. 1997. Secular increases in relative weight and adiposity among children over two decades: the Bogalusa Heart Study. *Pediatrics,* 99**,** 420-6.

FREEDMAN, D. S., WANG, J., OGDEN, C. L., THORNTON, J. C., MEI, Z., PIERSON, R. N., DIETZ, W. H. & HORLICK, M. 2007. The prediction of body fatness by BMI and skinfold thicknesses among children and adolescents. *Ann Hum Biol,* 34**,** 183-94.

FREEDSON, P. S. 1989. Field monitoring of physical activity in children. *Pediatr Exerc Sci,* 1**,** 8-18.

FRIEDENREICH, C. M. & ORENSTEIN, M. R. 2002. Physical activity and cancer prevention: etiologic evidence and biological mechanisms. *J Nutr,* 132**,** 3456S-3465S.

FULTON, J. E., DAI, S., STEFFEN, L. M., GRUNBAUM, J. A., SHAH, S. M. & LABARTHE, D. R. 2009. Physical activity, energy intake, sedentary behavior, and adiposity in youth. *Am J Prev Med,* 37**,** S40-9.

GORAN, M. I. 1997. Energy expenditure, body composition and disease risk in children and adolescents. *Proc Nutr Soc,* 56**,** 195-209.

GORAN, M. I. 1998. Measurement issues related to studies of childhood obesity: assessment of body composition, body fat distribution, physical activity, and food intake. *Pediatrics,* 101**,** 505-18.

GRACE, C., BEGUM, R., SUBHANI, S., KOPELMAN, P. & GREENHALGH, T. 2008. Prevention of type 2 diabetes in British Bangladeshis: qualitative study of community, religious, and professional perspectives. *BMJ,* 337.

GRASER, S. V., PANGRAZI, R. P. & VINCENT, W. J. 2007. Effects of placement, attachment, and weight classification on pedometer accuracy. *J Phys Act Health,* 4**,** 359-69.

GRUBER, J. J. 1986. Physical activity and self-esteem development in children: a meta-analysis. *American Academy of Physical Education Papers,* 19**,** 330-348.

GRUND, A., DILBA, B., FORBERGER, K., KRAUSE, H., SIEWERS, M., RIECKERT, H. & MULLER, M. J. 2000. Relationships between physical activity, physical fitness, muscle strength and nutritional state in 5- to 11-year-old children. *Eur J Appl Physiol,* 82**,** 425-38.

HALLAL, P. C., VICTORA, C. G., AZEVEDO, M. R. & WELLS, J. C. K. 2006. Adolescent physical activity and health. *Sports Med,* 36**,** 1019-30.

HANDS, B. & PARKER, H. 2008. Pedometer-determined physical activity, BMI, and waist girth in 7- to 16-year-old children and adolescents. *J Phys Act Health,* 5 Suppl 1**,** S153-65.

HANDS, B., PARKER, H. & LARKIN, D. 2006. Physical activity measurement methods for young people: a comparative study. *Meas Phys Educ Exerc Sci,* 10**,** 203-14.

HASKELL, W. L. & KIERNAN, M. 2000. Methodologic issues in measuring physical activity and physical fitness when evaluating the role of dietary supplements for physically active people. *Am J Clin Nutr,* 72**,** S541-50.

HATANO, Y. 1993. Use of the pedometer for promoting daily walking exercise. *ICHPER,* 29**,** 4-8.

HEA 1992. Allied Dunbar national fitness survey: main findings: a report on activity patterns and fitness levels commissioned by the Sports Council and Health Education Authority. London.

HEATH, G. W., PATE, R. R. & PRATT, M. 1993. Measuring Physical Activity Among Adolescents. *Public Health Rep,* 108**,** S42-6.

HERMAN, G. T. 2009. *Fundamentals of computerized tomography: Image reconstruction from projection*, Springer.

HERMAN, K. M., CRAIG, C. L., GAUVIN, L. & KATZMARZYK, P. T. 2009. Tracking of obesity and physical activity from childhood to adulthood: the Physical Activity Longitudinal Study. *Int J Pediatr Obes,* 4**,** 281-8.

HEYMSFIELD, S., WANG, Z., VISSER, M., GALLAGHER, D. & PIERSON JR, R. 1996. Techniques used in the measurement of body composition: an overview with emphasis on bioelectrical impedance analysis. *Am J Clin Nutr,* 64**,** S478-84.

HIMES, J. H. & DIETZ, W. H. 1994. Guidelines for overweight in adolescent preventive services: recommendations from an expert committee. The Expert Committee on Clinical Guidelines for Overweight in Adolescent Preventive Services. *Am J Clin Nutr,* 59**,** 307-16.

HIRSCHLER, V., ARANDA, C., CALCAGNO MDE, L., MACCALINI, G. & JADZINSKY, M. 2005. Can waist circumference identify children with the metabolic syndrome? *Arch Pediatr Adolesc Med,* 159**,** 740-4.

HOSSAIN, P., KAWAR, B. & EL NAHAS, M. 2007. Obesity and diabetes in the developing world - a growing challenge. *N Engl J Med,* 356**,** 213-215.

HOUTKOOPER, L. B., GOING, S. B., LOHMAN, T. G., ROCHE, A. F. & VAN LOAN, M. 1992. Bioelectrical impedance estimation of fat-free body mass in children and youth: a cross-validation study. *J Appl Physiol,* 72**,** 366-73.

HOUTKOOPER, L. B., LOHMAN, T. G., GOING, S. B. & HALL, M. C. 1989. Validity of bioelectric impedance for body composition assessment in children. *J Appl Physiol,* 66**,** 814-21.

HU, F. 2008. Measurement of Adiposity and body Composition. *In:* HU, F. (ed.) *Obes Epidemiol.* New York: Oxford University Press.

HU, F., MANSON, J., STAMPFER, M., COLDITZ, G. A., SPEIZER, F. & WILLETT, W. 2001. Diet, lifestyle and the risk of type 2 diabetes mellitus in women. *N Engl J Med,* 345**,** 790-7.

HUBERT, H., GUINHOUYA, C. B., ALLARD, L. & DUROCHER, A. 2008. Comparison of the diagnostic quality of body mass index, waist circumference and waist-to-height ratio in screening skinfold-determined obesity among children. *J Sci Med Sport*.

INCHLEY, J. C., CURRIE, D. B. & TODD, J. M. 2005. Persistant socio-demographic differences in physical activity among Scottish schoolchildren 1990-2002. *Eur J Public Health,* 15**,** 386-8.

IVY, J. L., ZDERIC, T. W. & FOGT, D. L. 1999. Prevention and treatment of non-insulin dependent diabetes mellitus. *Ex Sport Sci Rev,* 27**,** 1-35.

IWATA, F., HARA, M., OKADA, T., HARADA, K. & LI, S. 2003. Body fat ratios in urban Chinese children. *Pediatr Int,* 45**,** 190-192.

JACKSON-LEACH, R. & LOBSTEIN, T. 2006. Estimated burden of paediatric obesity and co-morbidities in Europe. Part 1. The increase in the prevalence of child obesity in Europe is itself increasing. *Int J Pediatr Obes,* 1**,** 26-32.

JAGO, R., WATSON, K., BARANOWSKI, T., ZAKERI, I., YOO, S., BARANOWSKI, J. & CONRY, K. 2006. Pedometer reliability, validity and daily activity targets among 10- to 15-year-old boys. *J Sports Sci,* 24**,** 241-51.

JANZ, K. F., DAWSON, J. D. & MAHONEY, L. T. 2000. Tracking physical fitness and physical activity from childhood to adolescence: the Muscatine study. *Med Sci Sports Exerc,* 32**,** 1250-57.

JANZ, K. F., WITT, J. & MAHONEY, L. T. 1995. The stability of children's physical activity as measured by accelerometry and self-report. *Med Sci Sports Exerc,* 27**,** 1326-32.

KELDER, S. H., PERRY, C. L., KLEPP, K. & LYTLE, L. L. 1994. Longitudinal tracking of adolescent smoking, physical activity and food choice behaviors. *Am J Pub Health,* 84**,** 1121-1126.

KELLY, L. A., REILLY, J. J., FAIRWEATHER, S. C., BARRIE, S., GRANT, S. & PATON, J. Y. 2004. Comparison of two accelerometers for assessment of physical activity in preschool children. *Pediatr Exerc Sci,* 16**,** 324-33.

KEMPER, H. C., TWISK, J. W., VAN MECHELEN, W., POST, G. B., ROOS, J. C. & LIPS, P. 2000. A fifteen-year longitudinal study in young adults on the relation of physical activity and fitness with the development of bone mass: the Amsterdam Growth and Health Longitudinal Study. *Bone,* 27**,** 847-53.

KILANOWSKI, C. K., CONSALVI, A. R. & EPSTEIN, L. H. 1999. Validation of an electronic pedometer for measurement of physical activity in children. *Pediatr Exerc Sci,* 11.

KOHL, H. W. I. & HOBBS, K. E. 1998. Development of physical activity behaviors among children and adolescents. *Pediatrics,* 101**,** 549-554.

KOMIYA, H., MASUBUCHI, Y., MORI, Y. & TAJIMA, N. 2008. The validity of body mass index criteria in obese school-aged children. *Tohoku J Exp Med,* 214**,** 27-37.

KOTTKE, F. J. 1980. From reflex to skill: the training of coordination. *Arch Phys Med Rehabil,* 61**,** 551-61.

KUCZMARSKI, R. J., OGDEN, C. L., GRUMMER-STRAWN, L. M., FLEGAL, K. M., GUO, S. S., WEI, R., MEI, Z., CURTIN, L. R., ROCHE, A. F. & JOHNSON, C. L. 2000. CDC Growth Charts: United States. *Adv Data,* 314**,** 1-27.

KWON, S., JANZ, K. F., BURNS, T. L. & LEVY, S. M. 2011. Association between light-intensity physical activity and adiposity in childhood. *Pediatr Exerc Sci,* 23**,** 218-29.

LACHOWYCZ, K. & JONES, A. P. 2011. Greenspace and obesity: a systematic review of the evidence. *Obes Reviews,* 12**,** e183-9.

LAPORTE, R. E., MONTOYE, H. J. & CASPERSEN, C. J. 1985. Assessment of physical activity in epidemiological research: problems and prospects. *Public Health Rep,* 100**,** 131-46.

LAURSON, K., EISENMAN, J., WELK, G. J., WICKEL, E., GENTILE, D. & WALSH, D. 2008a. Evaluation of youth pedometer-determined physical activity guidelines using receiver operator characteristic curves. *Prev Med,* 46**,** 419-24.

LAURSON, K. R., EISENMANN, J. C., WELK, G. J., WICKEL, E. E., GENTILE, D. A. & WALSH, D. A. 2008b. Combined influence of physical activity and screen time recommendations on childhood overweight. *J Ped,* 153**,** 209.

LAZZER, S., BOIRIE, Y., MEYER, M. & VERMOREL, M. 2005. Which alternative method to dual-energy X-ray absorptiometry for assessing body composition in overweight and obese adolescents? *Arch Pediatr,* 12**,** 1094-1101.

LIDDLE, J. 1997. Method for evaluating research and guideline evidence. *New South Wales Public Health Bulletin,* 8.

LINDQUIST, C. H., REYNOLDS, K. D. & GORAN, M. I. 1999. Sociocultural determinants of physical activty among children. *Prev Med,* 29**,** 305-12.

LIVINGSTONE, M. B., COWARD, W. A. & PRENTICE, A. M. 1992. Daily energy expenditure in free-living children: comparison of heart-rate monitoring with the doubly labelled water method. *Am J Clin Nutr,* 56**,** 343-52.

LOUCAIDES, C. A., CHEDZOY, S. M. & BENNETT, N. 2003. Pedometer-assesessed physical activity in Cypriot children. *Eur Phy Educ Rev,* 9**,** 43-55.

MACINTYRE, S. & MUTRIE, N. 2004. Socioeconomic differences in cardiovasculare disease and physical activity: stereotypes and reality. *J R Sco Health,* 124**,** 66-9.

MAFFEIS, C., PINELLI, L. & ZAFFANELLO, M. 1995. Daily energy expenditure in free-living conditions in obese and non-obese children: comparison of doubly labelled water method and heart rate monitoring. *Int J Obes Relat Metab Disord,* 19**,** 671-7.

MAHAR, M. & ROWE, D. 2002. Criterion-Related Evidence. *In:* WELK, G. J. (ed.) *Physical Activity Assessment for Health-Related Research.* Champaign, Illinois: Human Kinetics.

MALINA, R. M. 1996. Tracking of physical activity and physical fitness across the lifespan. *Res Q Exerc Sport,* 67**,** S48-57.

MANNAN, N., BOUCHER, B. J. & EVANS, S. J. 2000. Increased waist size and weight in relation to consumption of Areca catechu (betel-nut); a risk factor for increased glycaemia in Asians in east London. *Br J Nutr,* 83**,** 267-75.

MANSON, J., NATHAN, D., KROLEWSKI, A., STAMPFER, M., WILLETT, W. & HENNEKENS, C. 1992. A prospective study of exercise and incidence of diabetes among US male physicians. *J AM Med Assoc,* 268**,** 63-7.

MARGHAM, T., MAGRO, M. & HUDSON, Z. 2008. Pedometer-defined physical activity and body composition in 11 to 12 year old children in East London. A cross-sectional pilot study. London: Barts and the London School of Medicine & Dentistry.

MAST, M., SONNICHSEN, A., LANGNASE, K., LABITZKE, K., BRUSE, U., PREUB, U. & MULLER, M. J. 2002. Inconsistencies in bioelectrical impedance and anthropometric measurements of fat mass in a field study of prepubertal children. *Br J Nutr,* 87**,** 163-75.

MATHERS, C., VOS, T. & STEVENSON, C. 1999. The burden of disease and injury in Australia. Canberra, Australia: Australian Institute of Health and Welfare.

MATTOCKS, C., LEARY, S., NESS, A. & AL, E. 2007. Intraindividual variation of objectively measured physical activity in children. *Med Sci Sports Exerc,* 39**,** 622-29.

MCARDLE, W. D., KATCH, F. I. & KATCH, V. L. 1994. Energy transfer and physical activity. *Essentials of Exercise Physiology.* Malvern, Pennsylvania: Lea & Febiger.

MCCARTHY, H. D. 2006. Body fat measurements in children as predictors for the metabolic syndrome: focus on waist circumference. *Proc Nutr Soc,* 65**,** 385-92.

MCCARTHY, H. D., COLE, T. J., FRY, T., JEBB, S. A. & PRENTICE, A. M. 2006. Body fat reference curves for children. *Int J Obes,* 30**,** 598-602.

MCCARTHY, H. D., ELLIS, S. M. & COLE, T. J. 2003. Central overweight and obesity in British youth aged 11-16 years: cross sectional surveys of waist circumference. *BMJ,* 326**,** 624.

MCCARTHY, H. D., JARRETT, K. V. & CRAWLEY, H. F. 2001. The development of waist circumference percentiles in British children aged 5.0-16.9 y. *Eur J Clin Nutr,* 55**,** 902-7.

MCDONALD, C. M., WIDMAN, L., ABRESCH, R. T., WALSH, S. A. & WALSH, D. D. 2005. Utility of a step activity monitor for the measurement of daily ambulatory activity in children. *Arch Phys Med Rehabil,* 86**,** 793-801.

MCNAUGHTEN, D. & GABBERD, C. 2003. Physical exertion and immediate mental performance of sixth-grade children. *Percep Mot Skills,* 77**,** 1155-1159.

MELANSON, E., KNOLL, J., BELL, M., DONAHOO, W., HILL, J., NYSSE, L., LANNINGHAM-FOSTER, L., PETERS, J. & LEVINE, J. 2004. Commercially available pedometers: consideration for accurate step counting. *Prev Med,* 39**,** 361-68.

METCALF, B. S., VOSS, L. D., HOSKING, J., JEFFERY, A. N. & WILKIN, T. J. 2008. Physical activity at the government-recommended level and obesity-related health outcomes: a longitudinal study (Early Bird 37). *Arch Dis Child,* 93**,** 772-7.

MICHAUD, P., CAUDERAY, M., NARRING, F. & SCHUTZ, Y. 2002. Assessment of physical activity with a pedometer and its relationship with VO2max among adolescents in Switzerland. *Soz Praventimed,* 47**,** 107-15.

MISRA, A., WASIR, J. S. & VIKRAM, N. K. 2005. Waist circumference criteria for the diagnosis of abdominal obesity are not applicable uniformly to all populations and ethnic groups. *Nutrition,* 21**,** 969-76.

MITCHELL, H. H. 1962. *Comparative Nutrition of Man and Domestic Animals,* New York, Academic Press.

MITCHELL, R. & POPHAM, F. 2007. Greenspace, urbanity and health: relationships in England. *J Epidemiol Community Health,* 61**,** 681-3.

MITRE, N., LANNINGHAM-FOSTER, L., FOSTER, R. & LEVINE, J. A. 2009. Pedometer accuracy for children: can we recommend them for our obese population? *Pediatrics,* 123**,** e127-31.

MORENO, L. A., FLETA, J., MUR, L., SARRIA, A. & BUENO, M. 1998. Fat distribution in obese and non-obese children and adolescents. *J Paedr Gastr Nutr,* 27**,** 176-180.

MORRIS, J. N., HEADY, J. A., RAFFLE, P. A. B., PARKS, J. W. & ROBERTS, C. G. 1953. Coronary heart disease and physical activity of work. *Lancet,* 265**,** 1111-20.

MOSSBERG, H. O. 1989. 40-year follow-up of overweight children. *Lancet,* 2**,** 491-3.

MOTL, R. W., BIRNBAUM, A. S., KUBIK, M. Y. & DISHMAN, R. K. 2004. Naturally occurring changes in physical activity are inversely related to depressive symptoms during early adolescence. *Psychosomatic Medicine,* 66**,** 336-342.

MRC. 2011. *Epidemiology Unit* [Online]. Cambridge, UK. Available: www.mrc-epid.cam.uk/Unit/How/FunctionalTeams/Anthropometry/ [Accessed 25 July 2011].

MUST, A., DALLAL, G. E. & DIETZ, W. H. 1991. Reference data for obesity: 85th and 95th percentiles of body mass index and triceps skinfold thickness. *Am J Clin Nutr,* 53**,** 839-46.

NAKAE, S., OSHIMA, Y. & ISHII, K. 2008. Accuracy of spring-levered and piezo-electric pedometers in primary school Japanese children. *J Physiol Anthropol,* 27**,** 233-9.

NG, C., MARSHALL, D. & WILLOWS, N. D. 2006. Obesity, adiposity, physical fitness and activity levels in Cree children. *Int J Circumpolar Health,* 65**,** 322-30.

NHMRC 1999. How to review the evidence : systematic identification and review of the scientific literature. Canberra: National Health and Medical Research Council.

NHS 2010. Statistics on obesity, physical activity and diet. *In:* HEALTH, D. O. (ed.).

NIGHTINGALE, C. M., RUDNICKA, A. R., OWEN, C. G., COOK, D. G. & WHINCUP, P. H. 2011. Patterns of body size and adiposity among UK children of South Asian, black African–Caribbean and white European origin: Child Heart And health Study in England (CHASE Study). *Int J Epidemiol,* 40**,** 33-44.

NOCON, M., HIEMANN, T., MULLER-RIEMENSCHNEIDER, F., THALAU, F., ROLL, S. & WILLICH, S. N. 2008. Association of physical activity with all-cause and cardiovascular mortality: a systematic review and meta-analysis. *Eur J Cardiovasc Prev Rehab,* 15**,** 239-46.

NOLAND, M., DANNER, F., DEWALT, K. & AL, E. 1990. The measurement of physical activity in young children. *Res Q Exerc Sport,* 61**,** 146-53.

NORDSTROM, P., THORSEN, K., NORDSTROM, G., BERGSTROM, E. & LORENTZON, R. 1995. Bone mass, muscle strength and different body constitutional parameters in adolescent boys with a low or moderate exercise level. *Bone,* 17**,** 351-6.

NORRIS, R., CARROLL, D. & COCHRANE, R. 1992. The effects of physical activity and exercise training on psychological stress and well-being in an adolescent population. *J Psychosom Res,* 36**,** 55-65.

NPI. 2010. *London's Poverty Profile - Tower Hamlets* [Online]. Trust for London, New Policy Institute. Available: http://www.londonspovertyprofile.org.uk/indicators/boroughs/tower-hamlets/ [Accessed 12 Oct 2011].

O'HARA, H. M., BARANOWSKI, T. & SIMMONS-MORTON, B. G. 1989. Validity of the observation of children's physical activity. *Res Q Exerc Sport,* 60**,** 42-7.

OLIVER, M., SCHOFIELD, G. M., KOLT, G. S. & SCHLUTER, P. J. 2007. Pedometer accuracy in physical activity assessment of preschool children. *J Sci Med Sport,* 10**,** 303-10.

ONS 2001. Census 2001. London: Office of National Statistics.

ONS. 2011. *Neighbourhood Statistics: Tower Hamlets* [Online]. London: Office for National Statistics. Available: http://www.neighbourhood.statistics.gov.uk/dissemination/ [Accessed 12 Oct 2011].

OWEN, C. G., NIGHTINGALE, C. M., RUDNICKA, A. R., COOK, D. G., EKELUND, U. & WHINCUP, P. H. 2009. Ethnic and gender differences in physical activity levels among 9-10-year-old children of white European, South Asian and African-Caribbean origin: the Child Heart Health Study in England (CHASE Study). *Int J Epidemiol,* 38**,** 1082-1093.

OZDOBA, R., CORBIN, C. & LE MASURIER, G. 2004. Does reactivity exist in children when measuring activity levels with unsealed pedometers? *Pediatr Exerc Sci,* 16**,** 158-66.

PAFFENBARGER, R. S., HYDE, R. T., WING, A. L., LEE, I. M., JUNG, D. L. & KAMPERT, J. B. 1993. The association of changes in physical activity level and other lifestyle characteristics with mortality among men. *N Engl J Med,* 328**,** 538-45.

PATE, R. R. 2010. Assessing the level of physical activity in children. *In:* BOUCHARD, C. & KATZMARZYK, P. T. (eds.) *Physical Activity and Obesity.* Champaign, Il.: Human Kinetics.

PATE, R. R., O'NEILL, J. R. & MITCHELL, J. 2010. Measurement of Physical Activity in Preschool Children. *Med Sci Sports Exerc,* 42**,** 508-12.

PATEL, M., PHILLIPS-CAESAR, E. & BOUTIN-FOSTER, C. 2011. Barriers to lifestyle behavioral change in migrant South Asian populations. *J Immmigrant Minority Health,* [Epub ahead of print].

PORTNEY, L. & WATKINS, M. 2000a. Principles of Measurement. *Foundations of Clinical Research: Applications to Practice.* 2 ed. Upper Saddle River, NJ: Prentice-Hall.

PORTNEY, L. & WATKINS, M. 2000b. Reliability. *Foundations of Clinical Research: Application to Practice.* Upper Saddle, NJ: Prentice-Hall.

PORTNEY, L. & WATKINS, M. 2000c. Sampling. *Foundations of Clinical Research: Application to Practice.* Upper Saddle, NJ: Prentice-Hall.

PORTNEY, L. & WATKINS, M. 2000d. Statistical Inference. *Foundations of Clinical Research: Applications to Practice.* Upper Saddle, NJ: Prentice-Hall.

PORTNEY, L. & WATKINS, M. 2000e. Statistical measures of reliability. *Foundations of Clinical Research: Applications to Practice.* 2 ed. Upper Saddle River, NJ: Prentice Hall.

PRENTICE, A. M. & JEBB, S. A. 1995. Obesity in Britain: gluttony or sloth? *BMJ,* 311**,** 437-439.

PUHL, J., GREAVES, K., HOYT, M. & BARANOWSKI, T. 1990. Children’s Activity Rating Scale (CARS): description and calibration. *Res Q Exerc Sport,* 61**,** 26-36.

RAI, D. & FINCH, H. 1997. *Physical Activity "From Our Point of View": Attitudes and Barriers to Physical Activity Among South Asian and Black Communities*, Health Development Agency.

RAMIREZ-MARRERO, F. A., SMITH, B. A., SHERMAN, W. M. & KIRBY, T. E. 2005. Comparison of methods to estimate physical activity and energy expenditure in African American children. *Int J Sports Med,* 26**,** 363-371.

RAUSTORP, A. & LUDVIGSSON, J. 2007. Secular trends of pedometer-determined physical activity in Swedish school children. *Acta Paediatr,* 96**,** 1824.

RAUSTORP, A., MATTSSON, E., SVENSSON, K. & STAHLE, A. 2006. Physical activity, body composition and physical self-esteem: a 3-year follow-up study among adolescents in Sweden. *Scand J Med Sci Sports,* 16**,** 258-66.

RAUSTORP, A., PANGRAZI, R. P. & STAHLE, A. 2004. Physical activity level and body mass index among schoolchildren in south-eastern Sweden. *Acta Paediatr,* 93**,** 400-4.

REIDPATH, D. D., BURNS, C., GARRARD, J., MAHONEY, M. & TOWNSEND, M. 2002. An ecological study of the relationship between social and environmental determinants of obesity. *Health Place,* 8**,** 141-5.

REY-LOPEZ, J. P., VICENTE-RODRIGUEZ, G., ORTEGA, F. B., RUIZ, J. R., MARTINEZ-GOMEZ, D., DE HENAUW, S., MANIOS, Y., MOLNAR, D., POLITO, A., VERLOIGNE, M., CASTILLO, M. J., SJOSTROM, M., DE BOURDEAUDHUIJ, I. & MORENO, L. A. 2010. Sedentary patterns and media availability in European adolescents: The HELENA study. *Prev Med,* 51**,** 50-5.

RIDDOCH, C. J. & BOREHAM, C. A. G. 1995. The health-related physical activity of children. *Sports Med,* 19**,** 86-102.

RIDDOCH, C. J., MATTOCKS, C., DEERE, K., SAUNDERS, J., KIRKBY, J., TILLING, K., LEARY, S. D., BLAIR, S. N. & NESS, A. R. 2007. Objective measurement of levels and patterns of physical activity. *Arch Dis Child,* 92**,** 963-9.

ROMERI, E., BAKER, A. & GRIFFITHS, C. 2006. Mortality by deprivation and cause of death in England and Wales, 1999-2003. *Health Stat Q***,** 19-34.

ROTHON, C., EDWARDS, P., BHUI, K., VINER, R. M., TAYLOR, S. & STANSFELD, S. A. 2010. Physical activity and depressive symptoms in adolescents: a prospective study. *BMC Medicine,* 8**,** 1-9.

ROWE, D. A., MAHAR, M. I., RAEDEKE, T. D. & LORE, J. 2004. Measuring physical activity in children with pedometers: Reliability, reactivity, and replacement of missing data. *Pediatr Exerc Sci,* 16**,** 343-354.

ROWE, D. A., RAEDEKE, T. D., WIERSMA, L. D. & MAHAR, M. T. 2007. Investigating the Youth Physical Activity Promotion Model: Internal structure and external validity evidence for a potential measurement model. *Pediatr Exerc Sci,* 19**,** 420-435.

ROWLAND, T. W. 1998. The biological basis of physical activity. *Med Sci Sports Exerc,* 30**,** 392-9.

ROWLANDS, A. V., ESTON, R. G. & INGLEDEW, D. K. 1997. Measurement of physical activity in children with particular reference to the use of heart rate and pedometry. *Sports Med,* 24**,** 258-72.

ROWLANDS, A. V., ESTON, R. G. & INGLEDEW, D. K. 1999. Relationship between activity levels, aerobic fitness and body fat in 8- to 10-yr-old children. *J Appl Physiol,* 86**,** 1428-35.

SALLIS, J. F. 1991. Self-report measures of children's physical activity. *J Sch Health,* 61**,** 215-19.

SALLIS, J. F., ALCAREZ, J. E., MCKENZIE, T. L. & HOVELL, M. F. 1999. Predictors of change in children's physical activity over 20 months: variations by gender and level of adiposity. *Am J Prev Med,* 16**,** 222-229.

SALLIS, J. F. & OWEN, N. 1999. *Physical activity and behavioral medicine,* Thousand Oaks, Ca., Sage.

SALLIS, J. F., PROCHASKA, J. J. & TAYLOR, W. C. 2000. A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc,* 32**,** 963-975.

SALLO, M. & SILLA, R. 1997. Physical activity with moderate to vigorous intensity in pre-school and first-grade children. *Pediatr Exerc Sci,* 4**,** 44-54.

SAMMONS, P., WEST, A. & HIND, A. 1997. Accounting for variation in pupil attainment at the end of Key Stage ! *Br Educ Res J,* 23**,** 489-511.

SANDERS, C. E., FIELD, T. M., DIEGO, M. & KAPLAN, M. 2000. Moderate involvement in sports is related to lower depression levels among adolescents. *Adolescence,* 35**,** 793-7.

SARIS, W. H. 1985. The assessment and evaluation of daily physical activity in children. A review. *Acta Paediatr Scand,* 318**,** 37-48.

SARNI, R. S., DE SOUZA, F. I., SCHOEPS DDE, O., CATHERINO, P., DE OLIVEIRA, M. C., PESSOTTI, C. F., KOCHI, C. & COLUGNATI, F. A. 2006. [Relationship between waist circumference and nutritional status, lipid profile and blood pressure in low socioeconomic level pre-school children]. *Arq Bras Cardiol,* 87**,** 153-8.

SARRIA, A., MORENO, L. A., GARCIA-LLOP, L. A., FLETA, J., MORELLON, M. P. & BUENO, M. 2001. Body mass index, triceps skinfold and waist circumference in screening for adiposity in male children and adolescents. *Acta Paediatr,* 90**,** 387-92.

SAXENA, S., AMBLER, G., COLE, T. J. & MAJEED, A. 2004. Ethnic group differences in overweight and obese children and young people in England: cross sectional survey. *Arch Dis Child,* 89**,** 30-6.

SCHAEFER, F., GEORGI, M., WUHL, E. & SCHARER, K. 1998. Body mass index and percentage fat mass in healthy German schoolchildren and adolescents. *Int J Obes Relat Metab Disord,* 22**,** 461-9.

SCHMITZ, K. H., JACOBS, D. R., HONG, C.-P., STEINBERGER, J., MORAN, A. & SINAIKO, A. R. 2002. Association of physical activity with insulin sensitivity in children. *Int J Obes,* 26**,** 1310-16.

SCHMITZ, K. H., TREUTH, M. & HANNAN, P. 2005. Predicting energy expenditure from accelerometry counts in adolescent girls. *Med Sci Sports Exerc,* 37**,** 155-61.

SCHOELLER, D. A., RAVUSSIN, E., SCHUTZ, Y., ACHESON, K. J., BAERTSCHI, P. & JEQUIER, E. 1986. Energy expenditure by doubly-labeled water: Validation in humans and proposed calculations. *Am J Physiol,* 250**,** R823-30.

SCHOFIELD, G., SCHOFIELD, L., HINCKSON, E. A. & MUMMERY, W. K. 2009. Daily step counts and selected coronary heart disease risk factors in adolescent girls. *J Sci Med Sport,* 12**,** 148.

SCRUGGS, P. W. 2007a. A comparative analysis of pedometry in measuring physical activity of children. *Med Sci Sports Exerc,* 39**,** 1837-1846.

SCRUGGS, P. W. 2007b. Quantifying activity time via pedometry in fifth- and sixth-grade physical education. *J Phys Act Health,* 4**,** 215-27.

SCRUGGS, P. W., BEVERIDGE, S. K., EISENMAN, P. A., WATSON, D. L., SHULTZ, B. B. & RANSDELL, L. B. 2003. Quantifying physical activity via pedometry in elementary physical education. *Med Sci Sports Exerc,* 35**,** 1065-71.

SCRUGGS, P. W., BEVERIDGE, S. K., WATSON, D. L. & CLOCKSIN, B. D. 2005. Quantifying physical activity in first through fourth grade physical education via pedometry. *Res Q Exerc Sport,* 76**,** 166-75.

SEIDELL, J. C., BAKKER, C. J. & VAN DER KOOY, K. 1990. Imaging techniques for measuring adipose-tissue distribution - a comparison between computed tomography and 1.5-T magnetic resonance. *Am J Clin Nutr,* 51**,** 953-7.

SHEPHERD, R. J. 1997. Curricular physical activity and academic performance. *Pediatr Exerc Sci,* 9**,** 113-125.

SINGH, A. S., MULDER, C., TWISK, J. W., VAN MECHELEN, W. & CHINAPAW, M. J. M. 2008. Tracking of childhood overweight into adulthood: a systematic review of the literature. *Obes Reviews,* 9**,** 474-88.

SIRARD, J. R. & PATE, R. R. 2001. Physical activity assessment in children and adolescents. *Sports Med,* 31**,** 439-54.

SLEMENDA, C. W., MILLER, J. Z., HUI, S. L., REISTER, T. K. & JOHNSTON, C. C. J. 1991. Role of physical activity in the development of skeletal mass in children. *J Bone Miner Res,* 6**,** 1227-33.

SOPHER, A. B., THORNTON, J. C., WANG, J., PIERSON JR, R., HEYMSFIELD, S. & HORLICK, M. 2004. Measurement of percentage of body fat in 411 children and adolescents: a comparison of dual-energy x-ray absorptiometry with a four-compartment model. *Pediatrics,* 113**,** 1285-90.

SPIEGELMAN, B. & FLIER, J. 2001. Obesity and the regulation of energy balance. *Cell,* 104**,** 531-543.

SPROSTON, K. & MINDELL, J. 2006. Health Survey for England 2004: the health of ethnic minority groups. London.

SPROSTON, K. & PRIMATESTA, P. 2003. Health Survey for England 2002. The health of children and young people. *London: The Stationary Office*.

SQUIRE, L. F. & NOVELLINE, R. A. 1997. *Squire's fundamentals of radiology,* Boston, MA, Harvard University Press.

STAMATAKIS, E., PRIMATESTA, P., CHINN, S., RONA, R. & FALASCHETI, E. 2005. Overweight and obesity trends from 1974 to 2003 in English children: what is the role of socioeconomic factors? *Arch Dis Child,* 90**,** 999-1004.

STAMATAKIS, E., WARDLE, J. & COLE, T. J. 2010. Childhood obesity and overweight prevalence trends in England: evidence for growing socioeconomic disparities. *Int J Obes,* 34**,** 41-7.

STARC, G. & STREL, J. 2011. Tracking excess weight and obesity from childhood to young adulthood: a 12-year prospective cohort study in Slovenia. *Public Health Nutr,* 14**,** 49-55.

STATSPORTS. 2012. *Statsports Technologies - Viper Pod* [Online]. Available: http://www.statsports.ie/viper-Pod.html [Accessed 06 Nov 2012].

STRAUSS, R. S., RODZILSKY, D., BURACK, G. & COLIN, M. 2001. Psychosocial correlates of physical activity in healthy children. *Arch Pediatr Adolesc Med,* 155**,** 897-902.

STRONG, W. B., MALINA, R. M., BLIMKIE, C. J., DANIELS, S. R., DISHMAN, R. K., GUTIN, B., HERGENROEDER, A. C., MUST, A., NIXON, P. A., PIVARNIK, J. M., ROWLAND, T. R., TROST, S. & TRUDEAU, F. 2005. Evidence based physical activity for school-aged youth. *J Pediatr,* 146**,** 732-7.

STRYCKER, L. A., DUNCAN, S. C., CHAUMETON, N. R., DUNCAN, T. E. & TOOBERT, D. J. 2007. Reliability of pedometer data in samples of youth and older women. *Int J Behav Nutr Phys Act,* 4**,** 4.

TAYLOR, R. W., JONES, I. E., WILLIAMS, S. M. & GOULDING, A. 2000. Evaluation of waist circumference, waist-to-hip ratio, and the conicity index as screening tools for high trunk fat mass, as measured by dual-energy X-ray absorptiometry, in children aged 3-19 y. *Am J Clin Nutr,* 72**,** 490-5.

TAYLOR, S. J., VINER, R., BOOY, R., HEAD, J., TATE, H., BRENTNALL, S. L., HAINES, M., BHUI, K., HILLIER, S. & STANSFELD, S. 2005. Ethnicity, socio-economic status, overweight and underweight in East London adolescents. *Ethn Health,* 10**,** 113-28.

TAYLOR, W. C., BLAIR, S. N., CUMMINGS, S. S., WUN, C. C. & MALINA, R. M. 1999. Childhood and adolescent physical activity patterns and adult physical activity. *Med Sci Sports Exerc,* 31.

TELAMA, R. 2009. Tracking of physical activity from childhood to adulthood: a review. *Obes Facts,* 2**,** 187-95.

TELAMA, R., YANG, X., VIIKARI, J., VALIMAKI, I., WANNE, O. & RAITAKARI, O. 2005. Physical activity from childhood to adulthood: a 21-year tracking study. *Am J Prev Med,* 28**,** 267-73.

TELFORD, A., SALMON, J., JOLLEY, D. & CRAWFORD, D. 2004. Reliability and Validity of Physical Activity Questionnaires for Children: The Children's Leisure Activities Study Survey (CLASS). *Pediatr Exerc Sci,* 16**,** 64-78.

THC 2005. Open Space Strategy. London: Tower Hamlets Council.

THC. 2011a. *Moving to a Tower Hamlets Secondary School* [Online]. Available: www.towerhamlets.gov.uk/default.aspx?page=439 [Accessed Aug 2011].

THC. 2011b. *Tower Hamlets: Borough Statistics* [Online]. Tower Hamlets Council. Available: http://www.towerhamlets.gov.uk/lgsl/901-950/916_borough_statistics.aspx [Accessed June 2011].

THEINTZ, G., BUCHS, B., RIZZOLI, R., SLOSMAN, D., CLAVIEN, H., SIZONENKO, P. C. & BONJOUR, J. P. 1992. Longitudinal monitoring of bone mass accumulation in healthy adolescents: evidence for a marked reduction after 16 years of age at the levels of lumbar spine and femoral neck in female subjects. *J Clin Endocrinol Metab,* 75**,** 1060-5.

THOMAS, C., NIGHTINGALE, C. M., DONIN, A. S., RUDNICKA, A. R., OWEN, C. G., SATTAR, N., COOK, D. G. & WHINCUP, P. H. 2012. Socio-economic position and type 2 diabetes risk factors: patterns in UK children of South Asian, black African-Caribbean and white European origin. *PLoS One,* 7**,** e32619.

TOKUNAGA, K., MATSUZAWA, Y., ISHIKAWA, K. & TARUI, S. 1983. A novel technique for the determination of body fat by computed tomography. *Int J Obes,* 7**,** 437-45.

TOMPKINS, C. L., MORAN, K., PREEDOM, S. & BROCK, D. W. 2011. Physical activity-induced improvements in markers of insulin resistance in overweight and obese children and adolescents. *Current Diabetes Reviews,* 7**,** 164-170.

TOMPOROSKI, P. D. 2003. Cognitive and behavioral responses to acute exercise in youths: a review. *Pediatr Exerc Sci,* 15**,** 348-359.

TREMBLAY, M. S., INMAN, J. W. & WILLMS, J. D. 2000. The relationship between physical activity, self-esteem, and academic achievement in 12-year-old children. *Pediatr Exerc Sci,* 12**,** 312-323.

TREUTH, M. S., SHERWOOD, N. E., BUTTE, N. F., MCCLANAHAN, B., OBARZANEK, E., ZHOU, A., AYERS, C., ADOLPH, A., JORDAN, J., JACOBS, D. R. & ROCHON, J. 2003. Validity and reliability of activity measures in African-American girls for GEMS. *Med Sci Sports Exerc,* 35**,** 532-9.

TROIANO, R. P., BRIEFEL, R. R., CARROLL, M. D. & BIALOSTOSKY, K. 2000. Energy and fat intake of children and adolescents in the United States: data from the health and nutrition examination surveys. *Am J Clin Nutr,* 72**,** 1343s-1353s.

TROST, S. G., PATE, R. R., FREEDSON, P. S., SALLIS, J. F. & TAYLOR, W. C. 2000. Using objective physical activity measures with youth: how many days of monitoring are needed? *Med Sci Sports Exerc,* 32**,** 426-31.

TROST, S. G., SIRARD, J. R., DOWDA, M., PFEIFFER, K. A. & PATE, R. R. 2003. Physical activity in overweight and nonoverweight preschool children. *Int J Obes Relat Metab Disord,* 27**,** 834-9.

TROST, S. G., WAY, R. & OKLEY, A. D. 2006. Predictive validity of three Actigraph energy expenditure equations for children. *Med Sci Sports Exerc,* 38**,** 380-7.

TUDOR-LOCKE, C., HATANO, Y., PANGRAZI, R. P. & KANG, M. 2008. Revisiting "How many steps are enough?". *Med Sci Sports Exerc,* 40**,** S537-43.

TUDOR-LOCKE, C., MCCLAIN, J. J., HART, T. L., SISSON, S. B. & WASHINGTON, T. L. 2009. Pedometry methods for assessing free-living youth. *Res Q Exerc Sport,* 80**,** 175-84.

TUDOR-LOCKE, C., PANGRAZI, R. P., CORBIN, C. B., RUTHERFORD, W. J., VINCENT, S. D., RAUSTORP, A., TOMSON, L. M. & CUDDIHY, T. F. 2004. BMI-referenced standards for recommended pedometer-determined steps/day in children. *Prev Med,* 38**,** 857-64.

TUDOR-LOCKE, C., WILLIAMS, J. E., REIS, J. P. & PLUTO, D. 2002. Utility of pedometers for assessing physical activity: convergent validity. *Sports Med,* 32**,** 795-808.

USDHHS 2001. President's Council on Physical Fitness and Sports. The President's

Challenge Physical Activity and Fitness Awards Program. *US Department of Health and Human Services*.

VALIMAKI, M. J., KARKKAINEN, M., LAMBERG-ALLARDT, C., LAITINEN, K., ALHAVA, E. & HEIKKINEN, J. 1994. Exercsie, smoking and calcium intake during adolescence and early adulthood as determinants of peak bone mass. *BMJ,* 309**,** 230-5.

VAN KREEL, B., COX-REYVEN, N. & SOETERS, P. 1998. Determination of total body water by multifrequency bio-electrical impedance: development of several models. *Med Biol Eng Comput,* 36**,** 337-45.

VEITCH, J., SALMON, J. & BALL, K. 2010. Individual, social and physical environmental correlates of children's active free-play: a cross-sectional study. *Int J Behav Nutr Phys Act,* 7.

VINCENT, S. D. & PANGRAZI, R. P. 2002. An examination of the activity patterns of elementary school children. *Pediatr Exerc Sci,* 14**,** 432-41.

VINCENT, S. D., PANGRAZI, R. P., RAUSTORP, A., TOMSON, L. M. & CUDDIHY, T. F. 2003. Activity levels and body mass index of children in the United States, Sweden, and Australia. *Med Sci Sports Exerc,* 35**,** 1367-73.

VINER, R. M., CLARK, C., TAYLOR, S. J., BHUI, K., KLINEBERG, E., HEAD, J., BOOY, R. & STANSFELD, S. A. 2008. Longitudinal risk factors for persistent fatigue in adolescents. *Arch Pediatr Adolesc Med,* 162**,** 469-75.

VINER, R. M., HAINES, M. M., HEAD, J. A., BHUI, K., TAYLOR, S. J., STANSFELD, S. A., HILLIER, S. & BOOY, R. 2006. Variations in associations of health risk behaviors among ethnic minority early adolescents. *J Adolesc Health,* 38**,** 15-23.

WANG, Y., BEYDOUN, M. A., LIANG, L., CABALLERO, B. & KUMANYIKA, S. K. 2008. Will All Americans Become Overweight or Obese? Estimating the Progression and Cost of the US Obesity Epidemic. *Obesity,* 16**,** 2323-2330.

WARD, D. S., SAUNDERS, R. P. & PATE, R. R. 2007. The Role of Theory in Understanding Physical Activity Behaviour. *Physical Activity: Interventions in Children and Adolescents.* Champaign, IL: Human Kinetics.

WELK, G., WICKEL, E., PETERSON, M., HEITZLER, C., FULTON, J. & POTTER, L. 2007. Reliability and validity of questions on the youth media campaign longitudinal survey. *Med Sci Sports Exerc,* 39**,** 612-21.

WELK, G. J., CORBIN, C. B. & DALE, D. 2000. Measurement issues in the assessment of physical activity in children. *Res Q Exerc Sport,* 71**,** S59-73.

WESTON, A. T., PETOSA, R. & PATE, R. R. 1997. Validation of an instrument for measurement of physical activity in youth. *Med Sci Sports Exerc,* 29**,** 138-143.

WHINCUP, P. H., GILG, J. A., OWEN, C. G., ODOKI, K., ALBERTI, K. G. & COOK, D. G. 2005. British South Asians aged 13-16 years have higher fasting glucose and insulin levels than Europeans. *Diabet Med,* 22**,** 1275-77.

WHINCUP, P. H., GILG, J. A., PAPACOSTA, O., SEYMOUR, C., MILLER, G. J., ALBERTI, K. G. & COOK, D. G. 2002. Early evidence of ethnic differences in cardiovascular risk: cross sectional comparison of British South Asian and white children. *BMJ,* 324**,** 1-6.

WHINCUP, P. H., NIGHTINGALE, C. M., OWEN, C. G., RUDNICKA, A. R., GIBB, I., MCKAY, C. M., DONIN, A. S., SATTAR, N., ALBERTI, K. G. & COOK, D. G. 2010. Early emergence of ethnic differences in type 2 diabetes precursors in the UK: the Child Heart and Health Study in England (CHASE Study). *PLoD Med,* 7.

WHITAKER, R. C., WRIGHT, J. A., PEPE, M. S., SEIDEL, K. D. & DIETZ, W. H. 1997. Predicting obesity in young adulthood from childhood and parental obesity. *N Engl J Med,* 337**,** 869-73.

WHO 1995. Physical status: the use and interpretation of anthropometry. Geneva: WHO.

WHO 1997. Obesity: Preventing and managing the global epidemic. Report of a WHO consulation on obesity. Geneva, Switzerland: World Health Organisation.

WHO 2004. Global Strategy on Diet, Physical Activity and Health. Geneva, Switzerland: World Health Organization.

WHO. 2005. *Preventing chronic disease: a vital investment* [Online]. Available: http://www.who.int/chp/chronic_disease_reports/contents/en/index.html [Accessed 15 Aug 2011].

WHO. 2011a. *Cardiovascular Disease* [Online]. Available: www.who.int/mediacentre/factsheets/fs317/en/index.html [Accessed August 2011].

WHO. 2011b. *Obesity and Overweight* [Online]. Available: www.who.int/mediacentre/factsheets/fs311/en/index.html [Accessed July 2011].

WICKRAMASINGHE, V. P., CLEGHORN, G. J., EDMISTON, K. A., MURPHY, A. J., ABBOTT, R. A. & DAVIES, P. S. 2005. Validity of BMI as a measure of obesity in Australian white Caucasian and Australian Sri Lankan children. *Ann Hum Biol,* 32**,** 60-71.

WILKS, D. C., BESSON, H., LINDROOS, A. K. & EKELUND, U. 2011. Objectively measured physical activity and obesity prevention in children, adolescents and adults: a systematic review of prospective studies. *Obes Rev,* 12**,** e119-29.

WILLIAMS, E. D., STAMATAKIS, E., CHANDOLA, T. & HAMER, M. 2011. Physical activity behaviour and coronary heart disease mortality among South Asian people in the UK: an observational longitudinal study. *Heart,* 97**,** 655-59.

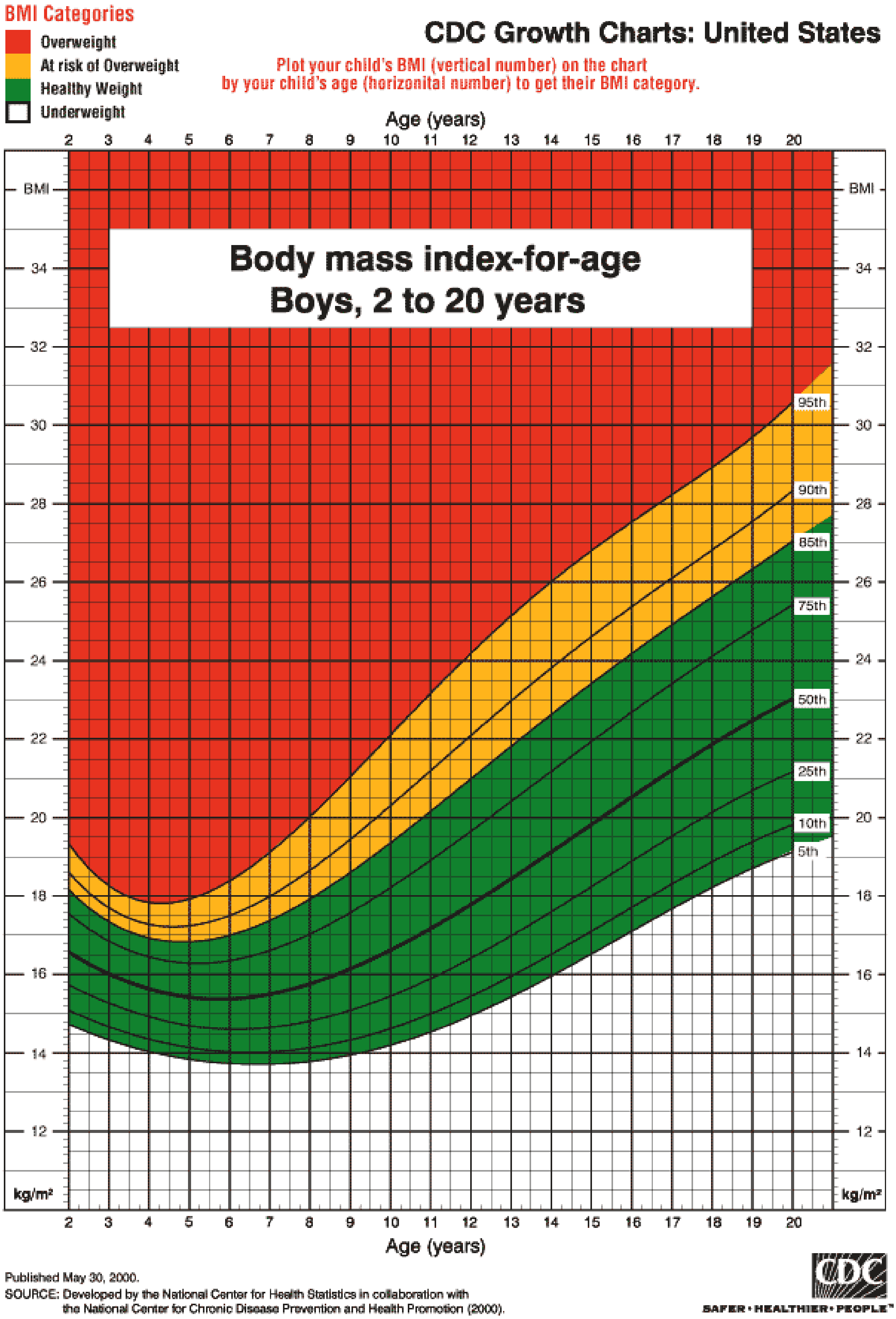
WILLIAMS, J. E., WAKE, M. & CAMPBELL, M. 2007. Comparing estimates of body fat in children using published bioelectrical impedance analysis equations. *Int J Pediatr Obes,* 2**,** 174-9.

WOODS, L. M., RACHET, B., RIGA, M., STONE, N., SHAH, A. & COLEMAN, M. P. 2005. Geographical variation in life expectancy at birth in England and Wales is largely explained by deprivation. *J Epidemiol Community Health,* 59**,** 115-20.

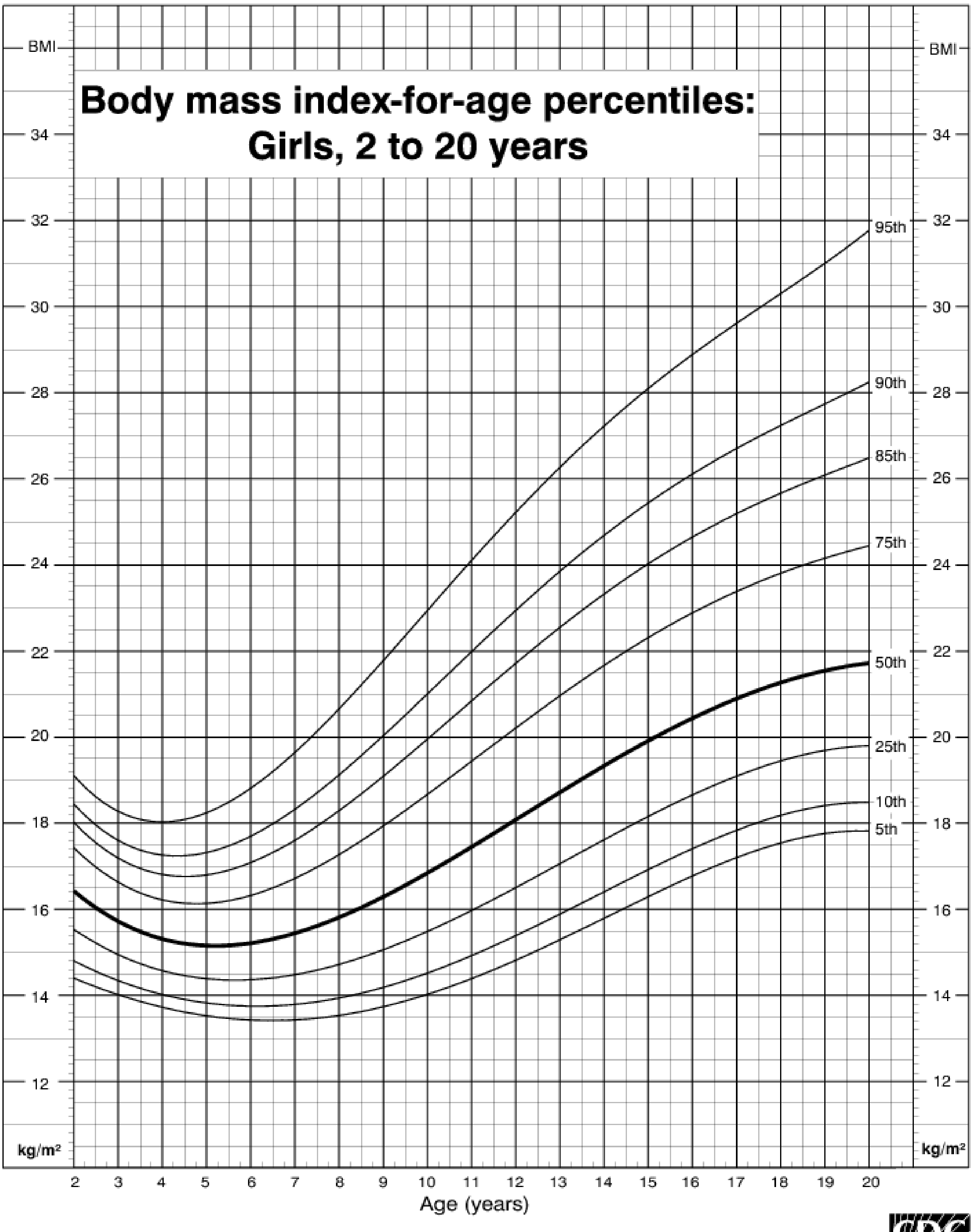
ZIMMERMANN, M. B., GUBELI, C., PUNTENER, C. & MOLINARI, L. 2004. Detection of overweight and obesity in a national sample of 6-12-y-old Swiss children: accuracy and validity of reference values for body mass index from the US Centers for Disease Control and Prevention and the International Obesity Task Force. *Am J Clin Nutr,* 79**,** 838-43.

APPENDICES

Appendix 1 – CDC BMI charts for boys and girls



CDC Growth Charts: United States



Published May 30, 2000.
SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

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Appendix 2 – Recruitment letter sent to school head-teachers

Barts and The London
School of Medicine and Dentistry

Centre for Sport and Exercise Medicine
Barts and the London School of Medicine and Dentistry
Mann Ward
The Mile End Hospital
Bancroft Road
London E1 4DG

Dear sir/madam,

My name is Eoin and I am a PhD student at the Centre for Sports and Exercise Medicine in Queen Mary, University of London. Part of our work here is to investigate to the relationship between physical activity and obesity in school-aged children. This is a very important area of research as childhood obesity is a very pertinent issue.

As part of this research, last year we carried out a successful pilot study at Morpeth School in Bethnal Green. We measured the activity levels and body composition data of the majority of students in Year 7 and found some interesting results regarding activity patterns and their relationship to obesity compared to previously published research in the UK and internationally.

This year, we hope to broaden the scope of our research by including more schools in the study. By doing so, we will be able to produce more accurate and meaningful results. These results will hopefully be used to combat the current obesity epidemic by helping to shape activity related guidelines and legislation.

With this in mind, I would like to know if you are interested in having your school participate in this very worthwhile study. As mentioned above, the more schools and students we get involved, the more beneficial our work will be. If you are interested, have any queries or would like more specific details about what the study entails, please to do not hesitate to contact myself or my supervisor, Dr. Zoe Hudson.

Yours Sincerely,

Eoin Mc Namara
Primary Investigator
Centre for Sport & Exercise Medicine
Tel: +44 (0)20 8223 8839
Email: e.mcnamara@qmul.ac.uk

Dr. Zoe Hudson PHD MCSP
Acting Centre Lead and Senior Clinical Lecturer
Centre for Sport & Exercise Medicine
Tel: +44 (0)20 8223 8255
Email: z.hudson@qmul.ac.uk

Appendix 3 – Study information sheet for students

Active Kids Study – Information Sheet for Students

What is the test for? We are a team of people from Queen Mary University that are interested in seeing how much exercise and activity you do each day. We are investigating the link between activity levels and body shape – the results of the test may be helpful in finding out how active young people should be.

Would you be interested in helping us by joining our project? All we need you to do is let us measure your height and weight and also do a test that looks to see how much body water you have. These are very simple quick tests that will be carried out during you P.E. class and your classmates will not see these being done. We will also ask you a couple of questions about exercise and any sport that you do.

After P.E., you will be given a pedometer to wear for one week. As the picture (below) shows, it is a small device you attach to your clothes. It measures how many steps you do per day. We will ask you to wear this all day, every day, for a week, you don't have to do anything else. After one week, we will come back to the school and collect them from you.

Why take part? At the end of the study, we will give everyone their own results – these will be private and only given to you. They will show you how many steps you are taking and compare this with how many steps you should be taking to stay healthy. By taking part, you are helping in a scientific experiment to find out how to make young people lead healthier lifestyles.

We are asking everyone in Year 7 if they want to take part. If you would like to take part that would be great, but if you don't, that's ok – you don't have to take place if you don't want to. You don't have to decide now, you can discuss with your family at home. I have an information sheet for your family to read as well.

If you do want to take part, please fill in the consent form (attached) with your parents and I will be back in one week to collect it.

Appendix 4 – Study information sheet for parents / guardians

Centre for Sport and Exercise Medicine
Barts and the London School of Medicine and Dentistry
Mann Ward
Mile End Hospital
Bancroft Road
London E1 4DG
Telephone: +44 (0)20 8223 8839
Fax: +44 (0)20 8223 8930

11th January 2010

YOU WILL BE GIVEN A COPY OF THIS INFORMATION SHEET

Physical activity levels in secondary schoolchildren

We would like to invite your son/daughter to participate in this original research project. They should only do it if they want to; and whether they decide to do it or not will make no difference to their care at school. Before you/they decide whether they want to take part, it is important for you both to understand why this is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information.

Physical activity is an important part of a healthy lifestyle and we know that physical inactivity and levels of obesity have been rising in children. The purpose of this study is to measure the activity levels in secondary school in a variety of different schools. The information gained will help us to see if children generally are undertaking enough activity, and if not, why not and what can we do about it. By taking part, each child will get feedback as to whether they are doing the minimum recommended amount of activity.

If they volunteer to take part a member of our research team will the school and take their height, weight, waist and body fat measurements. These tests are very simple and do not hurt in any way. They will then be asked a few questions on what types of physical activity they like, how they get to and from school and, if they don't do much sport or exercise, what things are stopping them doing more. This should only take 15 minutes of their time. They will then be given a pedometer which is the size of a small mobile phone, to wear for the next 7 days. This clips on easily to a belt or waistband and they will be shown how to put it on each morning. After a week we will come to the school and collect these back.

Any child can volunteer to take part in this study as long as they are in Year 7 and physically active. If they are unable to exercise for any reason, please let us know and we will see if they can still take part in this study.

There are no anticipated risks, inconvenience or discomfort in taking part in this study.

If they do decide to do this, we will give you their results if you want, and let you know if they are doing enough exercise/activity.

All data collected will be anonymised and treated in the strictest confidence and no one apart from the researcher at the University will be able to identify your child individually. They will be given a study number and all data collected will have their study number, not their name on this, so no one can identify them. The data sheet with their name and study number will be kept in a locked room in the Centre for Sports and Exercise Medicine at Queen Mary University of London. Only the Principal researcher has access to this information. Data will be stored in accordance with the Data protection Act

It is up to you and your child to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form on behalf of your child. If they decide to take part they are still free to withdraw at any time and without giving a reason.

In the unlikely event of them suffering any adverse effects as a consequence of their participation in this study, you will be compensated through Queen Mary University of London's 'No Fault Compensation Scheme'.

YOU WILL BE GIVEN A COPY OF THIS INFORMATION SHEET

Researcher: Eoin Mc Namara / E mail:E.McNamara@qmul.ac.uk
www.smd.qmul.ac.uk/sportsmed/

Appendix 5 – Consent form

Centre for Sport and Exercise Medicine
Barts and the London School of Medicine and Dentistry
The Mile End Hospital
Bancroft Road
London E1 4DG
Telephone: +44 (0)20 8223 8839

Title of Study: **Physical activity levels in secondary schoolchildren in Tower Hamlets – a pilot study**

Queen Mary Research Ethics Committee Ref: 2007/26

- Thanks to your child for considering taking part in this research. The person organising the research must explain the project to both of you before you agree to consent to your child taking part
- If you have any questions arising from the Information sheet given to you, please ask the researcher before you decide whether to join in. You will be given a copy of this Consent Form to keep and refer to at any time.
- I understand that if my child decides at any other time during the research that they no longer wish to participate in the project, I can notify the researchers involved and they can be withdrawn immediately.
- I consent to the processing of my child's personal information for the purpose of this research study. I understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.

Participants name:____

Parental Consent:
I ____________________________________ agree that the research project named above has been explained to me to my satisfaction and I agree for my son/daughter named above to take part in the study. I have read both the notes above and the Information Sheet about the project, and understand what the research study involves.
Signed:_______________________________________ Date:__________________________

Investigator's Statement:
I ____________________________________ confirm that I have carefully explained the nature, demands and any foreseeable risks (where applicable) of the proposed research to the volunteer.
Signed:_______________________________________ Date:__________________________

Yours sincerely,

Eoin Mc Namara
PhD Research Student
Centre for Sports and Exercise Medicine, QMUL
www.smd.ac.uk/sportsmed/

Please complete this form after you have read the Information Sheet and/or listened to an explanation about the research.

Appendix 6 – Ethical approval received from Queen Mary Research Ethics Committee

Queen Mary
University of London

Queen Mary, University of London
Room E16
Queen's Building
Queen Mary University of London
Mile End Road
London E1 4NS

Queen Mary Research Ethics Committee
Hazel Covill
Research Ethics Committee Administrator
Tel: +44 (0) 20 7882 2207
Email: h.covill@qmul.ac.uk

c/o Dr Zoe Hudson
Centre for Sports & Exercise Medicine
Mile End Hospital
Bancroft Road
Mile End

10th September 2009

To Whom It May Concern:

Re: QMREC2009/35 – Physical Activity Amongst Children in Tower Hamlets

The above study was conditionally approved by The Queen Mary Research Ethics Committee on the 8th July 2009. Full approval was ratified by Chair's Action on the 10th September 2009.

This approval is valid for a period of two years, (if the study is not started before this date then the applicant will have to reapply to the Committee).

Yours faithfully

Ms Elizabeth Hall – QMREC Chair.

Appendix 7 – Approval received from Tower Hamlets Children's Services

TOWER HAMLETS

Children, Schools and Families
Directorate
Strategy, Partnerships and
Performance
Tower Hamlets Children's Services
2nd Floor
Town Hall, Mulberry Place
5 Clove Crescent
London E14 2BG

Tel:020 7364 0429
E mail:crs@towerhamlets.gov.uk

Our Ref: CSRGF45
Date: 7th September 2009

Dear Eoin McNamara

Research Title: Investigating physical activities levels in Tower Hamlets adolescents

This is to confirm that your research proposal has been considered by the Tower Hamlets Research and Performance Development Team and has been approved, on the terms previously advised (as per e-mail communication – attached). The RGF should be informed of any significant changes that take place, including but not exclusively, change of scope, methodology or composition of investigative team.

Upon completion can you please submit a copy of your report to enable this information to be registered on the National Social Care Research Register.

Please complete the attached research process questionnaire and give us your feedback on the service that you have received from us. We want to ensure that we offer the best quality service to our users and your feedback is essential in improving our services further.

Please do not hesitate to contact the Research and Performance Development Team should you need any further assistance.

We wish you well in your research study.

Yours sincerely,

V. Wheawell

Vicky Wheawell
Research and Performance Development Manager

Appendix 8 – Testing questionnaire form

YOUR DETAILS

Study #:______________ Gender: M ❑ F ❑

D.O.B.: / / Age:__________

ETHNICITY

What category best describes you – what is your ethnicity/race?

White UK ❑ Irish ❑

Greek ❑ Turkish ❑

Orthodox Jewish❑ Kurdish ❑ Other (specify)_______________

Mixed White & Black Caribbean ❑ White & Black African ❑

White & Asian ❑ Other (specify)_______________

Asian Bangladeshi ❑ Pakistani ❑

Indian ❑ Other (specify)_______________

Black Caribbean ❑ African ❑

Somali ❑ British ❑ Other (specify)_______________

Chinese ❑ Vietnamese ❑ Other (specify)________

____

FAMILY & HOME

Do you get free school meals? Yes ❑ No ❑

Does your dad work? Yes ❑ No ❑ Job?___

____

Does your mum work? Yes ❑ No ❑ Job?___

____

At home, do you have the following: TV? Yes ❑ No ❑

Internet? Yes ❑ No ❑

Car(s) Yes ❑ #____ No ❑

Do you share a bedroom? Yes ❑ No ❑

Appendix 9 – International BMI cut off points for overweight & obesity (Cole, 00)

Table 4 International cut off points for body mass index for overweight and obesity by sex between 2 and 18 years, defined to pass through body mass index of 25 and 30 kg/m^2 at age 18, obtained by averaging data from Brazil, Great Britain, Hong Kong, Netherlands, Singapore, and United States

	Body mass index 25 kg/m^2		Body mass index 30 kg/m^2	
Age (years)	**Males**	**Females**	**Males**	**Females**
2	18.41	18.02	20.09	19.81
2.5	18.13	17.76	19.80	19.55
3	17.89	17.56	19.57	19.36
3.5	17.69	17.40	19.39	19.23
4	17.55	17.28	19.29	19.15
4.5	17.47	17.19	19.26	19.12
5	17.42	17.15	19.30	19.17
5.5	17.45	17.20	19.47	19.34
6	17.55	17.34	19.78	19.65
6.5	17.71	17.53	20.23	20.08
7	17.92	17.75	20.63	20.51
7.5	18.16	18.03	21.09	21.01
8	18.44	18.35	21.60	21.57
8.5	18.76	18.69	22.17	22.18
9	19.10	19.07	22.77	22.81
9.5	19.46	19.45	23.39	23.46
10	19.84	19.86	24.00	24.11
10.5	20.20	20.29	24.57	24.77
11	20.55	20.74	25.10	25.42
11.5	20.89	21.20	25.58	26.05
12	21.22	21.68	26.02	26.67
12.5	21.56	22.14	26.43	27.24
13	21.91	22.58	26.84	27.76
13.5	22.27	22.98	27.25	28.20
14	22.62	23.34	27.63	28.57
14.5	22.96	23.66	27.98	28.87
15	23.29	23.94	28.30	29.11
15.5	23.60	24.17	28.60	29.29
16	23.90	24.37	28.88	29.43
16.5	24.19	24.54	29.14	29.56
17	24.46	24.70	29.41	29.69
17.5	24.73	24.85	29.70	29.84
18	25	25	30	30

* Table reproduced directly from Cole, 00

Appendix 10 – Data collected to measure reliability of indicators of adiposity

Study ID	Height		Weight		WC		Impedance		%BF	
	1	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
1	152	152	42.8	42.7	69	69	965	969	39.1	39.2
2	145	145.5	34.1	34.1	65	64	963	967	32.8	32.6
3	145	145	34.1	34.1	67	67	968	966	33.1	32.9
4	156	156	38.6	38.6	69	69	981	981	31.5	31.5
5	141	141	33.7	33.7	66	67	945	949	34.7	34.9
6	140	140	37.8	37.8	74	74	942	950	41.1	41.5
7	156.5	156.5	44.2	44.2	70	70	954	958	37.2	37.4
8	142.5	142.5	34.9	34.9	69	69	1007	1007	38.3	38.4
9	151.5	151.5	39.9	39.9	72	72	1008	1002	37.9	37.6
10	157.5	157.5	50.2	50.3	78	77	922	924	41.5	41.7
11	135.5	135	28.2	28.2	59	59	926	921	29.1	29.3
12	150.5	150.5	47	47	83	83	938	938	43.4	43.4
13	150.5	150.5	47.2	47.2	79	79	791	783	38.2	37.9
14	155.5	155.5	45.4	45.4	74	73	869	862	35.9	35.7
15	147.5	147.5	32.7	32.7	61	61	875	875	23.5	23.5
16	163.5	163.5	67.6	67.6	86	86	814	814	47.9	47.9
17	145.5	146	48	48.1	81	81	823	824	43.2	43.1
18	146	146	47.5	47.5	77	77	827	825	42.6	42.5
19	141.5	141.5	37.9	37.9	73	74	862	862	36.4	36.4
20	141.5	141.5	32.6	32.5	66	66	802	801	24.9	24.6
21	136	136	30.9	30.9	64	64	883	883	31.2	31.3
22	143	143.5	34.8	34.8	69	71	834	837	29.1	28.9
23	146	146	35.9	35.9	67	67	845	845	29.0	29.0
24	144.5	144.5	37.6	37.6	70	70	848	838	32.9	32.5
25	143.5	143.5	54.2	54.2	91	90	851	855	50.3	50.4
26	151.5	151.5	36.5	36.5	58	58	902	906	28.2	28.4
27	145	145	43.6	43.6	77	77	904	909	42.36	42.6
28	152.5	153	45.8	45.6	81	79	737	725	33.32	32.3
29	136.5	136.5	34.6	34.6	71	72	774	788	31.38	32.2
30	157.5	157	40	39.8	74	75	713	709	20.71	20.6

Appendix 11 – Data collected to measure pedometer reliability

Pedometer	Test 1	Test 2	Test 3	Test 4
# 1	103	104	100	101
# 2	100	100	101	99
# 3	103	101	105	99
# 4	101	101	99	99
# 5	103	100	101	105
Mean	102.0	101.2	101.2	100.6
St. Dev.	1.41	1.64	2.28	2.61

Appendix 12 - Histograms for anthropometric and activity data

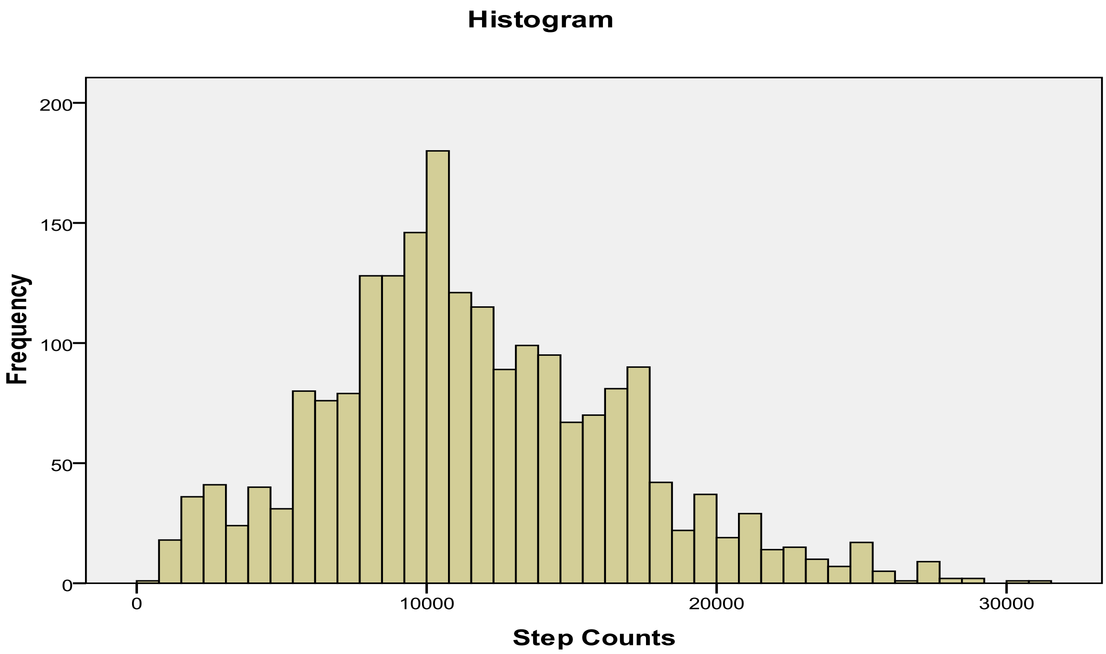

Figure 1 – Histogram for Step Counts Data

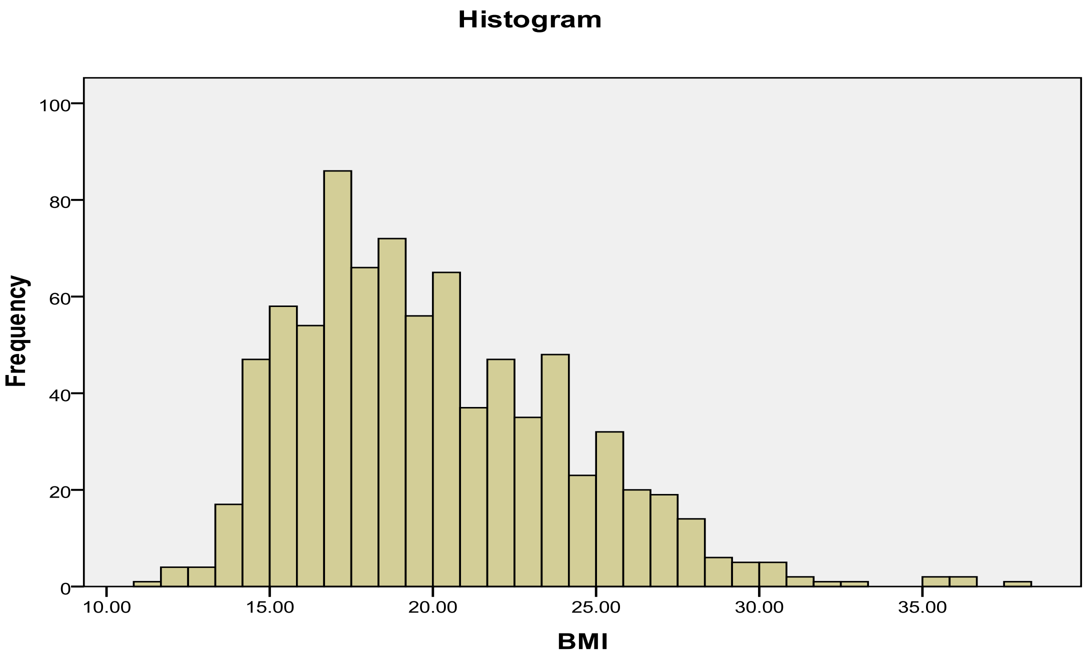

Figure 2 – Histogram Body Mass Index Data

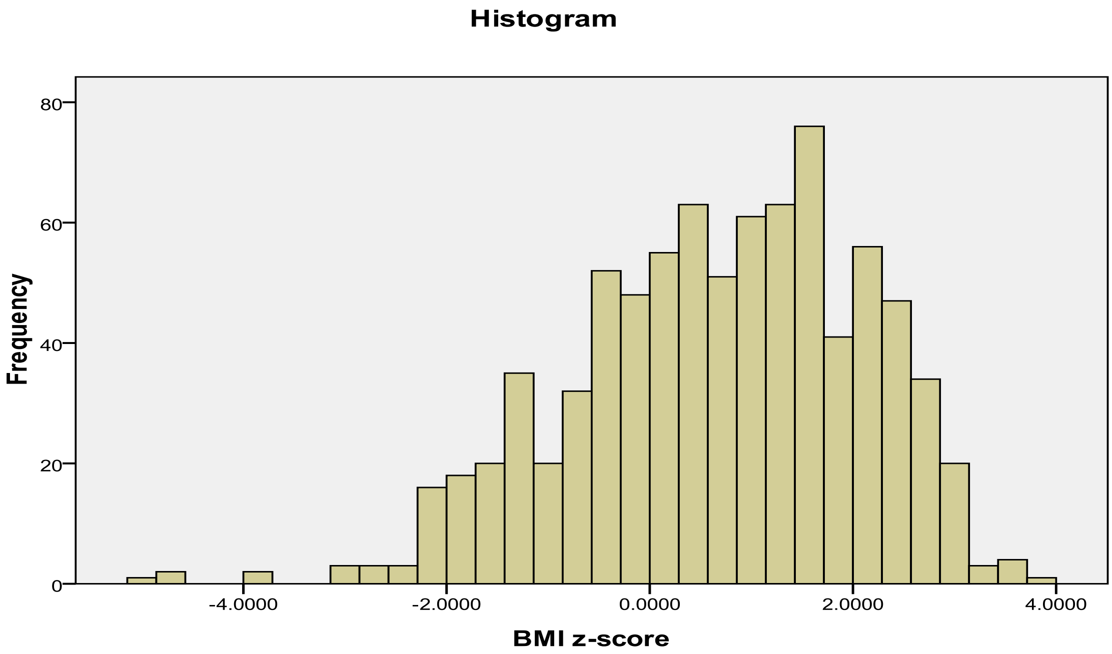

Figure 3 – Histogram for BMI Z-score Data

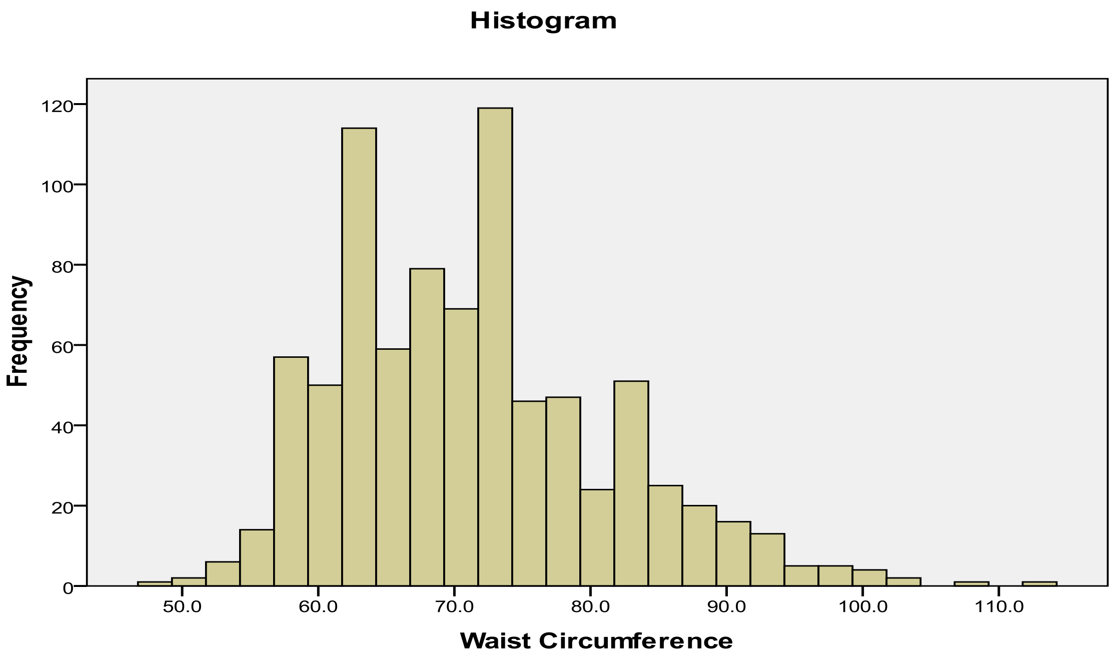

Figure 4– Histogram for Waist Circumference Data

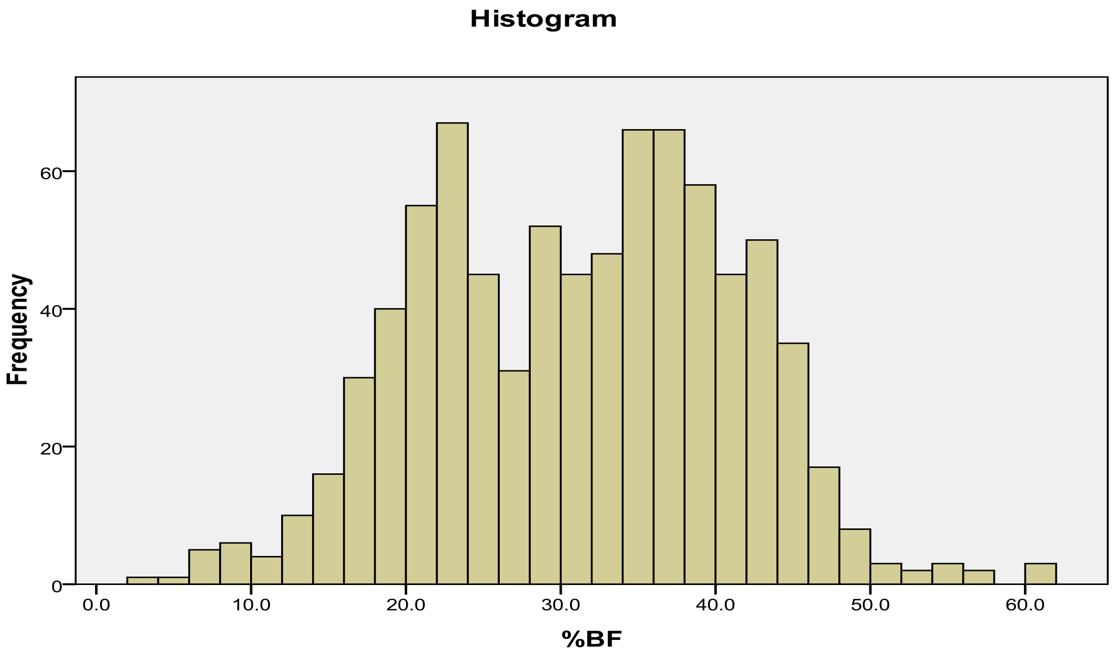

Figure 5 – Histogram Plot for %BF Data

Appendix 13 – Raw Data

ID	Sex	Age	Ethnic	FSM	Dad	Mum	TV	Web	Car	Bed	DST	Height	Weight	BMI	BMIZ	WC	%BF	Imp	Mon	Tues	Wed	Thur	Fri	Sat	Sun
BET001	f	12	Bang	0	2	0	1	1	0	0	1	151	40.4	17.7	-0.1826	74	23.8	658	11649	10108	12757		12173		
BET002	m	12	Bang	0	0	0	1	1	1	0	1	147	30.9	14.3	-2.0259	65	14.3	768	17454	9602	10444	4033	9781	6706	10251
BET003	m	12	Blk Afr.	1	1	0	1	0	0	1	1	151	48.8	21.4	1.5016	71	36.9	717	7783	15422		8511		3799	
BET004	m	11	Bang	0	0	0	1	1	2	1	1	135	29.0	15.9	-0.5359	61	5.8	502		17345	9345	10365	9153	8433	8001
BET005	m	12	Blk Afr								1	157	46.0	18.7	0.5756	64	32.8	793	14509	9141	18177	7149			
BET006	m	12	Bang	1	1	0	1	1	0	0	1	144	37.3	18.0	0.2858	63	20.8	587		10051	8233	9183			
BET007	m	11	Bang	0	1	1	1	1	1	0	1	152	40.3	17.4	0.2948	73	28.4	784	10587	14549	7819	9626	11044		
BET008	m	12	Blk Afr	1	1	0	1	1	1	1	1	158	42.2	16.9	-0.2494	64	25.6	755				2030		11564	15388
BET009	f	12	Bang	0	0	0	1	1	1	0	1	158	69.8	28.0	2.5624	76	52.5	852	12830	11305	10112	9455	9822	12578	4723
BET010	m	12	Bang								1	148	60.9	27.8	2.7464	91	43.9	558				11048	9177	8482	
BET011	m	12	Wh. UK								1	148	40.7	18.6	0.5424	64	32.7	803		8757			9919		
BET012	f	11	Bang								1	152.5	57.7	24.8	2.1820	87	42.0	654	10587	14549	13260	13141	8726	3443	9648
BET013	m	11	Bang								1	152	64.8	28.0	2.9203	93	44.4	547	5944	6309	12830	12405	9032		
BET014	m	12	Blk Afr								1	155	64.2	26.7	2.5931	75	43.2	572		9328		9564			
BET015	m	11	Bang	0	0	0	1	0	0	0	1	156	44.6	18.3	0.6869	77	34.0	850	7527		10587	15547	7819	5509	
BET016	m	12	Bang	0	0	0	1	0	0	0	1	146	32.5	15.2	-1.2814	61	16.4	723				6756	15813	12915	
BET017	m	11	Bang								1	167.5	53.8	19.2	1.0160	79	34.5	779	9800	9263	8476		10645		
BET018	f	11	Bang	0	0	0	1	0	0	0	1	148	30.0	13.7	-2.2462	58	16.7	865		10883	8113	10393	10377		
BET019	m	11	Bang	0	0	0	1	0	0	0	1	138	29.6	15.5	-0.7718	64	24.5	843	9454				8113	10393	10377
BET020	m	11	Blk Car	0	0	0	1	0	0	0	1	158	63.2	25.3	2.5308	74	42.8	633	10003	12338	8536	13372	10368	8456	
BET021	m	12	SA Oth	0	0	0	1	0	0	0	1	154	55.4	23.4	1.9843	83	40.0	675			10022	12345	10345	10754	9654
BET022	m	12	Wh. UK	0	0	0	1	0	0	0	1	147	59.9	27.7	2.7352	76	43.9	566	9371			9584	8578	11336	
BET023	m	12	SA Oth	0	0	0	1	0	0	0	1	146	46.8	22.0	1.6502	78	37.6	709	14211		12543		8512	8812	12012
BET024	m	12	Wh. UK	0	0	0	1	0	0	0	1	159	51.4	20.3	1.1810	82	35.7	743			14301	8166	14157	2477	
BET025	f	12	Bang	0	1	0	1	1	1	1	1	141	47.4	23.8	1.7805	60	31.7	445	10702		10081	7364	11048		
BET026	f	11	Bang	1	1	0	1	1	1	1	1	150	44.4	19.7	0.8693	83	31.2	682	9842	12507	10018		10080	8148	
BET027	m	12	Wh. UK	0	2	0	1	1	1	0	1	137.5	29.1	15.4	-1.1786	58	13.9	676	12170				9770	10213	7261
BET028	m	12	Wh. UK	1	1	0	1	1	1	0	1	154	55.4	23.4	1.9843	74	41.2	713	12089		2624	14991			
BET029	f	12	Wh. UK	0	0	0	1	0	0	0	1	140	39.0	19.9	0.6751	80	26.9	590	11392	10504	11169	7806		12294	14667
BET030	m	11	SA Oth	0	1	1	1	1	1	0	1	148	62.6	28.6	2.9842	94	48.5	684	12042	8430	8445	12456			
BET031	f	12	Bang	1	1	1	1	1	0	1	1	149	32.4	14.6	-1.9375	58	11.8	694	5361		14621		9434	19367	
BET032	m	12	Blk Afr	0	0	0	1	1	0	0	1	158	55.3	22.2	1.7005	73	36.8	646	16079		10990				16812
BET033	m	12	SA Oth	1	1	0	1	1	1	1	1	156	57.6	23.7	2.0505	82	44.0	782		8829	20771	1512		8948	15446
BET034	m	12	SA Oth	0	1	0	1	1	1	0	1	160.5	69.6	27.0	2.6368	94	45.7	627		12012	13537	11412	10332	11322	

BET035	m	12	Bang	0	0	0	1	1	0	0	1	143.5	54.2	26.3	2.5317	91	44.7	677	12095				11683		8654
BET036	f	11	Bang	0	0	0	1	1	0	0	1	147	45.4	21.0	1.2688	80	36.0	726	9383	11620	12757		7118		
BET037	m	12	Bang	1	1	0	1	1	1	1	1	140	28.4	14.5	-1.8654	59	12.0	717	4226	13724	17655	11163			
BET038	m	12	Bang	1	1	1	1	0	2	1	1	156	41.5	17.1	-0.1704	65	16.6	531		4686		11163	17694		3894
BET039	m	11	Blk Afr	0	0	0	1	1	0	0	1	158	46.0	18.4	0.7278	70	23.8	572	10640			9693			
BET040	m	12	Wh. UK	1	1	0	1	1	0	1	1	135	27.7	15.2	-1.3159	63	16.2	728	17414	11268	9550	12173	6093		
BET041	m	12	Bang	0	0	0	1	0	1	0	1	154	44.4	18.7	0.5998	73	30.4	730							
BET042	m	12	Blk Afr	1	1	0	1	1	1	1	1	158.5	72.5	28.9	2.8808	76	48.8	653		10509	9453	14380			10898
BET043	m	12	Bang	0	1	1	1	1	2	1	1	166	47.5	17.2	-0.0748	69	27.0	740	9860	8942		8053			15310
BET044	f	12	Bang	0	0	0	1	0	0	0	1	147	47.2	21.8	1.2773	72	32.7	581			21168		8782		
BET045	m	12	SA Oth	0	1	0	1	0	0	0	1	153	37.5	16.0	-0.7632	70	13.7	581				9767	10441	11490	
BET046	m	12	SA Oth	0	0	0	1	1	1	1	1	147	37.7	17.4	0.0299	69	26.3	742	12138					13134	7186
BET047	m	11	Turk	0	0	0	1	1	1	0	1	147	44.0	20.4	1.4119	75	33.4	701	8767	10011			11070	13454	
BET048	m	11	Turk	0	1	1	1	1	1	1	1	153	62.3	26.6	2.7300	97	46.1	689	14167	9583	12069	10417	9252		
BET049	f	12	Wh. UK	0	0	0	1	1	0	0	1	145	36.3	17.3	-0.3925	67	20.6	639		7931			16543	17198	12878
BET050	f	11	Bang	0	1	0	1	1	1	1	1	145	34.9	16.6	-0.4209	68	23.5	750	4972	14261	9945	8126	12138	15267	
BET051	m	12	Blk Car	1	1	0	1	1	1	0	1	149	38.8	17.5	0.0448	71	28.3	782	14754	11654	11132		16102		
BET052	f	12	Wh. UK	0	0	0	1	0	0	0	1	161	44.8	17.3	-0.3838	65		x			13664	15113	10967	8666	
BET053	f	12	Bang	0	0	0	1	1	0	0	1	155	52.8	22.0	1.3144	72	38.5	717			13840	15024	10998	8711	
BET054	m	11	Bang	0	0	0	1	0	0	0	1	150	49.5	22.0	1.8618	78	37.5	698	8112	7967	13444	14651	10485		
BET055	m	11	Bang	0	0	0	1	0	0	0	1	153	65.6	28.0	2.9174	94	44.6	553		10314	6092	15717	15936	7654	10751
BET056	m	12	Wh. UK	1	1	0	1	1	1	0	1	148	44.5	20.3	1.1760	82	34.3	726	5866				8113	21345	8379
BET057	f	12	Bang	0	0	0	1	1	1	0	1	159	51.4	20.3	0.8208	73	35.5	738	11497	10187				9935	13964
BET058	m	12	SA Oth	0	0	0	1	0	1	0	1	150	60.0	26.7	2.5848	75	47.9	756	11800	12129					
BET059	m	11	Bang	1	1	0	1	1	1	1	1	159	49.2	19.5	1.1176	65	34.0	762			9458	14439			
BET060	m	11	Bang	1	1	0	1	1	1	0	1	142	38.6	19.1	1.0041	75	33.3	782			13087				5600
BET061	m	12	Bang	1	1	0	1	1	1	0	1	149.5	34.3	15.3	-1.2103	63	21.0	801	24568	11388	6083	7841	10125		9117
BET062	m	12	Wh. UK	1	1	0	1	1	1	0	1	159	49.2	19.5	0.8836	65	32.9	729							
BET063	f	11	Bang	0	0	0	1	1	1	0	1	147	37.5	17.4	-0.0607	76	22.2	662	12911	13433	15435	11578	8681		
BET064	m	12	Bang	0	0	0	1	1	0	1	1	165	48.6	17.9	0.2232	70	28.4	726	14446	12403	14164	6443			
BET065	m	12	Blk Afr	0	0	0	1	1	0	0	1	159	65.0	25.7	2.4333	75	45.9	721		21154			15124	6712	9862
BET066	m	12	Bang	1	1	0	1	1	0	1	1	145	33.0	15.7	-0.9717	57	8.6	538	10539	7932			7076		20786
BET067	m	11	Bang	1	1	0	1	1	0	0	1	150.5	45.9	20.3	1.3820	78	27.9	555	8918	13681	11696				
BET068	m	11	Bang								1	157	46.4	18.8	0.8849	76	32.9	783			8732	6953	13720	16999	11517
BET069	f	12	Bang	1	1	0	1	1	1	1	1	152	40.0	17.3	-0.3697	69	20.6	615	14477		13298				
BET070	m	12	Blk Afr	1	1	1	1	1	1	0	1	159	60.5	23.9	2.1048	74	46.8	859	14165	16966	19095	9499			9546
BET071	m	11	Bang	0	0	0	1	1	0	0	1	150	52.8	23.5	2.1908	87	45.3	840	10505	15412	11565				
BET072	m	11	Blk Afr	0	0	0	1	0	0	0	1	155						640			16967	9986	10289	10424	17384

BET073	f	11	Bang	0	1	0	1	1	0	0	1	149	42.9	19.3	0.7279	76	39.1	910			15242	10883		14521	12737
BET074	f	12	Bang	1	1	1	1	0	1	1	1	159	79.5	31.4	3.0442	77	56.6	862			13155	12222	19613	7456	17755
BET075	m	12	Bang	1	1	1	1	1	1	1	1	149	26.6	12.0	-4.5840	58		714					15977		8296
BET076	f	12	Wh. UK	0	1	1	1	0	2	1	1	128	38.2	23.3	1.6576	74	41.4	733	14646			12254	8326		
BET077	m	11	Bang	0	1	0	1	1	1	1	1	145	44.2	21.0	1.6054	72	34.2	681	14740	11444	10631				14424
BET078	m	11	Bang	1	1	1	1	0	1	1	1	159	65.0	25.7	2.5944	93	43.8	641		10916	15675	14802	11803		
BET079	m	12	Blk Afr	0	1	0	1	0	0	0	1	159	66.8	26.4	2.5476	75	44.7	631	20894	16168		12170	13081	7387	7528
BET080	m	12	Bang	1	1	0	1	1	1	1	1	154	39.0	16.4	-0.5067	73	27.4	840	19357	18374	11245	10769		11136	12035
BET081	m	12	Bang	0	0	0	1	1	2	1	1	141	29.9	15.0	-1.4332	59	13.2	689	12236	11157	11731	6328	21775		
BET082	m	12	Bang	0	0	0	1	1	1	0	1	161	38.5	14.9	-1.5750	59	22.3	865			10234	13564	17548	16354	3576
BET083	m	11	Bang	0	0	0	1	1	1	0	1	157	50.6	20.5	1.4623	77	32.6	642	16272				10762		
BET084	m	11	Bang								1	145	30.4	14.5	-1.5658	64	11.9	714	16544		17645	15567		15464	
BET085	m	11	SA Oth	0	0	0	1	1	1	0	1	142	41.7	20.7	1.5074	70	43.3	923	10082	10118		16264	17242		
BET086	m	12	Wh. UK	0	1	0	1	1	0	1	1	138.5	34.3	17.9	0.2370	67	27.6	742	13166	12712		12011	13201		
BET087	f	12	Wh. UK	1	1	0	1	0	1	1	1	152	39.5	17.1	-0.4737	65	20.3	629			14984	15079	15858	15409	13704
BET088	m	12	Bang	1	1	1	1	1	2	1	1	159.5	61.0	24.0	2.1143	74	38.8	576			10235	14835			21011
BET089	m	11	Bang	0	0	0	1	1	1	1	1	141	32.0	16.1	-0.4243	61	18.2	691	17555	16744	17435	14935			
BET090	m	12	SA Oth	0	1	1	1	1	1	1	1	144	40.6	19.6	0.9261	71	28.6	644	16012	11044	17532	12243	11634	12045	11032
BET091	m	11	SA Oth	0	0	0	1	0	0	0	1	146	51.6	24.2	2.3358	86	38.9	609		19965	10578	13683			
BET092	m	11	Wh. UK	0	1	0	1	0	1	1	1	151	61.7	27.1	2.7924	95	46.6	687			12243	13192	13994	28054	12131
BET093	m	12	Bang	0	1	0	1	1	1	0	1	155	43.0	17.9	0.2448	72	29.0	760			12890	14579	24702		11825
BET094	m	11	Bang	1	1	1	1	1	1	1	1	141	39.1	19.8	1.2352	70	29.5	655	9989		12909	14507	16269	18011	
BET095	m	11	Blk Afr	1	1	0	1	0	1	0	1	149.5	36.6	16.4	-0.2609	63	16.3	613	2454	23640	17820	18074	11686	11503	7809
BET096	m	12	Bang	0	0	0	1	1	0	0	1	138.5	27.3	14.2	-2.0845	61	6.7	656	19998	22453	10507	16426			
BET097	m	11	Bang	0	1	0	1	0	0	1	1	140	34.9	17.8	0.4626	72	15.1	497	12999	14623	14481	14606	12427		15686
BET098	m	12	Bang	1	1	0	1	1	1	1	1	143	37.9	18.5	0.5228	64	31.4	779	24941			21378		6229	11153
BET099	m	11	Bang	1	1	1	1	1	1	1	1	133	25.2	14.2	-1.7422	64	16.5	802			17600	19343	20123	12565	
BET100	f	11	Wh. UK	0	1	0	1	1	1	0	1	160	59.9	23.4	1.8827	75	45.7	851			17220	9572		12286	18797
BET101	m	11	Bang	0	0	0	1	0	0	0	1	154	38.7	16.3	-0.2939	59	21.6	722	16706	13244	15323	10331	13653	17876	
BET102	m	11	Wh. UK	0	1	1	1	0	0	1	1	160	61.0	23.8	2.2632	90	42.6	717	27643	15011	11645	17476			
BET103	m	12	Bang	0	0	0	1	0	0	1	1	163.5	67.6	25.3	2.3610	86	47.0	775	17535	13603					
BET104	m	12	SA Oth	0	0	1	1	1	0	1	1	152	41.1	17.8	0.1944	69	33.6	880	18929	17372		21133	16577		11543
BET105	f	11	Wh. UK	0	0	0	1	0	0	0	1	160	69.6	27.2	2.6053	76	44.5	570	15465	13577	11058	12015			
BET106	m	12	Bang	0	0	1	1	1	1	1	1	151	57.6	25.3	2.3565	85	44.0	697			17643		20435	16321	
BET107	f	12	SA Oth	0	0	0	1	1	1	0	1	160.5	52.9	20.5	0.8869	73	31.8	605							
BET108	m	12	Wh. UK	0	0	0	1	0	0	1	1	132	56.0	32.1	3.2222	77	48.8	567	21611	18325			18295	1558	17373
BET109	f	11	Bang	0	0	0	1	1	2	1	1	149	31.3	14.1	-1.9409	62	9.2	695	21322	10166	12034	11430	7326		
BET110	m	12	Blk Afr	1	1	1	1	1	1	1	1	169.5	67.5	23.5	2.0135	73	42.7	715		16621	18904	17900	20319	8926	7675

BET111	m	11	Bang	0	0	0	1	1	0	0	1	160.5	44.8	17.4	0.2701	62	29.1	796			10502	19495	14003	23076	11895
BET112	m	12	Bang	0	0	0	1	0	0	0	1	136.5	33.2	17.8	0.2081	62	21.7	633							
BET113	f	12	Bang	0	0	0	1	0	1	0	1	153	62.0	26.5	2.3143	75	46.2	698	15122	15432	15169	15354	14354		
BET114	m	12	Bang	0	0	0	1	1	0	0	1	148.5	55.2	25.0	2.3155	84	39.3	565			6775	11833	19508	17577	15899
BET115	m	11	Blk Car	1	1	0	1	1	1	0	1	161	38.5	14.9	-1.2582	60	22.6	872				9654	1045	15432	9541
BET116	m	11	Bang	0	0	0	1	1	1	0	1	151	47.6	20.9	1.5640	77	39.8	831			12113	13032	13844	9474	23221
BET117	m	12	Bang	0	0	0	1	1	1	0	1	156.5	74.2	30.3	3.0430	101	55.5	868	19545	13811	20111	22432	26012		
BET118	m	11	Bang	0	0	0	1	0	0	0	1	138	28.7	15.1	-1.0980	59	12.7	681	19246	11907	16955				
BET119	f	12	Wh. UK	0	1	0	1	1	1	1	1	121	52.0	35.5	3.4720	85	60.5	819		23412	19649	17605	7085	15819	11410
BET120	f	12	Bang	1	1	0	1	1	0	1	1	141	30.9	15.5	-1.3191	61	23.2	824				15984	13242		
BET121	f	12	Bang	0	2	0	1	1	2	1	1	143	32.1	15.7	-1.2261	63	22.5	801				13253		15991	
BET122	m	11	Bang	1	1	0	1	0	1	0	1	140	30.3	15.5	-0.8276	59	20.7	786			12186	25254	12741		
BET123	m	12	SA Oth								1	142	37.6	18.6	0.5695	71	32.6	797	16078	14376	10076	16423	25314		
BET124	m	11	SA Oth								1	142	31.1	15.4	-0.8516	67	21.4	801	11276		14176	16172	14037	21227	14691
BET125	m	12	Bang	0	0	0	1	0	0	0	1	143	33.5	16.4	-0.5432	62	19.1	683	20134	13712	20143	16214	14123	18005	
BET126	m	11	Bang	0	0	0	1	0	0	0	1	153	54.7	23.4	2.1703	81	39.9	674	24471	18371	22572			20609	13799
BET127	m	12	Bang	0	0	0	1	0	0	0	1	157	54.3	22.0	1.6693	82	38.1	698	16410	16555	17172				
BET128	m	12	Bang								1	134	38.7	21.6	1.5430	72	36.6	714				14876	16289		
BET129	m	11	Blk Afr	0	0	0	1	0	0	0	1	142	33.4	16.6	-0.1553	59	20.3	693	16352	12456	17431	16459	17433		
BET130	m	12	Blk Afr								1	161	59.1	22.8	1.8580	74	39.7	683	23627	20843		5459	21174	19160	12799
BET131	m	11	Bang	0	0	0	1	0	0	0	1	143	47.5	23.2	2.1414	82	39.1	680		11087	30121	15057			
BET132	m	12	Bang								1	151	32.3	14.2	-2.1422	56	7.0	642				17007	16413	20261	15891
BET133	m	11	Blk Afr								1	138	33.0	17.3	0.2397	60	25.8	745	12434	27544	13573	26027		27007	
BIG001	f	12	SA Oth	0	0	0	1	0	0	0	0	147.5	44.5	20.5	0.8606	63	34.1	711	10178	11683	14752	5317	6744		
BIG002	f	11	Bang								0	148	36.0	16.4	-0.5043	62	21.0	710	13047		3555	16035	12577	20985	
BIG003	f	11	Bang								0	144.5	35.5	17.0	-0.2242	59.5	23.7	725	13354	12530	11063	18080	10040	10904	3079
BIG004	f	12	Wh. UK								0	155	56.5	23.5	1.7054	72.5	37.1	568	9121	12763	12436	12473	13562	5622	8995
BIG005	f	11	Blk. Afr								0	170.5	58.0	20.0	0.9418	69.5	30.7	577			13377	9742	15629	6564	5936
BIG006	f	11	Blk. Afr	1	1	0	1	1	1	0	0	149	35.0	15.8	-0.8660	58.5	17.5	695	13453	15453	7543	10433	13563		
BIG007	f	12	Bang	1	1	0	1	1	1	0	0	150	50.0	22.2	1.3808	69.5	39.1	729	17480	6054	15807	13362	17614	16077	5178
BIG008	f	12	Bang	1	1	0	1	1	1	0	0	151	46.5	20.4	0.8411	74.5	34.4	717	10216	8173	9684	11209	6464		
BIG009	f	12	Wh. UK	1	1	0	1	1	1	0	0	161	76.5	29.5	2.7930	102	48.5	593	8785	12271	12952	13179	10819	4010	2434
BIG010	f	11	Wh. UK	1	1	0	1	1	1	0	0	159	42.5	16.8	-0.3161	55	20.5	637	10947	6060	11785	5200			
BIG011	f	11	Bang	1	1	0	1	1	1	0	0	140.5	29.5	14.9	-1.3608	59.5	25.0	898	13203	11080	14209	14243	12881	22510	8672
BIG012	f	11	Blk. Car	1	1	0	1	1	1	0	0	164.5	55.5	20.5	1.1192	78	35.9	721							
BIG013	f	11	Bang	1	1	0	1	1	1	0	0	153	48.0	20.5	1.1177	72	36.2	757	16140	16200	15612	22001	25935		
BIG014	f	12	Wh. UK	0	0	2	1	1	0	0	0	156.5	57.5	23.5	1.6959	80	33.8	455			4454	6544	4335	6753	7683
BIG015	f	11	Bang	1	1	0	1	1	1	0	0	151	42.0	18.4	0.3905	69.5	30.4	759	15730	12695	10583	15258	13045	1431	2495

BIG016	f	11	Bang	1	1	0	1	1	1	0	0	142.5	31.0	15.3	-1.1593	61.5	22.1	826	10788	11398	10651	14202	11638	24104	5829
BIG017	f	11	Blk. Afr	1	1	0	1	1	1	0	0	153	57.0	24.3	2.0887	69.5	38.3	558		11776	12345	12544	13123		
BIG018	f	12	Wh. UK	1	1	0	1	1	1	0	0	162	70.0	26.7	2.3475	82.5	45.0	615							
BIG019	f	11	Bang	1	1	0	1	1	1	0	0	143.5	29.5	14.3	-1.7771	53	15.0	780			3238				
BIG020	f	11	Wh. UK	0	0	0	1	0	0	0	0	142	38.0	18.8	0.5540	59	26.9	659	4212	10356			1516	2243	
BIG021	f	12	Bang	0	0	0	1	0	0	0	0	142	39.0	19.3	0.4770	64	29.0	673	4711	10178	11679	14712	3914	5347	6746
BIG022	f	11	Bang	1	1	0	1	1	1	0	0	149	44.0	19.8	0.8979	67.5	31.8	695	11691	11862	10322	13904	11029	10764	7504
BIG023	f	12	Bang	1	1	0	1	1	1	0	0	158.5	43.0	17.1	-0.4641	63	27.1	772	6662	12713	8454	11828	4948	1545	5611
BIG024	f	11	Bang	0	2	0	1	1	1	0	0	144	31.0	14.9	-1.3571	58.5		339	12530	7625	10732	12908	6905	6956	13798
BIG025	f	11	Bang	0	2	0	1	1	1	0	0	150	40.5	18.0	0.2201	62.5	20.9	570	9376	6992	13989	7251	7045		
BIG026	f	11	Wh. UK	0	2	0	1	1	1	0	0	158.5	47.0	18.7	0.5023	67	33.1	795		7689	15207				
BIG027	f	12	Bang	1	1	0	1	1	1	0	0	138.5	31.0	16.2	-0.9604	57.5	30.7	911							
BIG028	f	12	Bang	0	2	0	1	1	1	0	0	138.5	34.0	17.7	-0.1798	57	30.7	813							
BIG029	f	12	Wh. UK	1	1	2	1	1	1	0	0	150.5	49.0	21.6	1.2184	67	34.9	647				14491	10644	11761	8567
BIG030	f	11	Bang	0	2	0	1	1	1	0	0	162.5	54.0	20.4	1.1006	66.5	38.1	800			11298	3700	7161	16251	
BIG031	f	12	Wh. UK	1	1	0	1	1	1	0	0	154	53.5	22.6	1.4692	71.5	35.6	591	12966	12144	15345	13119	8487	2440	10990
BIG032	f	11	Bang	1	1	0	1	1	1	0	0	147.5	39.5	18.2	0.2843	62	31.5	807	8668		8619	9754	9781	2819	4806
BIG033	f	12	Bang	0	2	0	1	1	1	0	0	149.5	46.0	20.6	0.9016	68	37.0	776	23244	21721	13268	22127	14045	10316	3437
BIG034	f	11	Bang	1	1	0	1	1	1	0	0	150	36.5	16.2	-0.6155	63	28.0	872	10488	6699	4979	12557	7580	13803	
BIG035	f	12	Bang	1	1	2	1	1	0	0	0	145	49.0	23.3	1.6552	83.5	41.9	750		6343	7563	6424			
BIG036	f	11	Wh. UK	0	0	0	1	0	0	0	0	144	39.0	18.8	0.5399	61	20.1	507	5762				5975		6473
BIG037	f	12	Wh. UK	0	2	0	1	1	1	0	0	154	45.0	19.0	0.3392	74	33.7	797	12992	14309	13461	24021	7834	8946	10631
BIG038	f	12	Bang	0	2	0	1	1	1	0	0	164.5	61.0	22.5	1.4650	70.5	37.5	614	6051	5066	6876	3731	8931	3647	2759
BIG039	f	11	Bang	1	1	2	1	1	1	1	0	152.5	42.0	18.1	0.2448	61	28.7	742	8256	13173	9744	10366	10930		
BIG040	f	11	Wh. UK	1	1	2	1	1	1	0	0	145.5	43.5	20.5	1.1308	67.5	31.9	652	6608		6018	6467	6647		
BIG041	f	12	Bang	0	2	0	1	1	1	0	0	157	42.5	17.2	-0.4035	68	24.3	696							
BIG042	f	11	Bang	0	2	0	1	1	1	0	0	134	26.0	14.5	-1.6695	48	18.3	812	6583	10168	10087	10770	9059	11460	6738
BIG043	f	11	Bang	0	0	0	1	0	0	0	0	153	48.0	20.5	1.1177	75	32.3	648	9441	8479	11882	12286	10284	8501	9805
BIG044	f	12	Wh. UK	0	0	0	1	1	0	0	0	153	39.5	16.9	-0.5840	64.5	32.3	918	9518	3210	9384	14985	13968	1434	3781
BIG045	f	11	Bang	1	1	2	1	1	1	0	0	141	32.0	16.1	-0.6832	57	20.2	728	15166	10530	8245	7987	10760	7885	2637
BIG046	f	11	Wh. UK	0	0	0	1	1	0	0	0	155	50.0	20.8	1.2105	63	29.9	549	15274	13785	8287	8077	14247	2166	3528
BIG047	f	11	Bang	1	1	1	1	1	1	1	0	139.5	57.5	29.5	2.9485	77.5	55.5	884							
BIG048	f	12	Wh. UK	0	0	0	1	1	0	0	0	150	46.0	20.4	0.8576	64.5	32.2	659	3504		11884	8222			
BIG049	f	11	Blk. Afr	1	1	2	1	1	1	1	0	162	59.5	22.7	1.7118	63.5	35.4	543							
BIG050	f	12	Bang	1	1	1	1	1	1	1	0	160	67.5	26.4	2.2930	83	47.1	724	2661	11809	10687	12059	9698		
BIG051	f	11	Blk. Car	0	0	2	1	1	0	0	0	156	43.5	17.9	0.1675	66.5	26.6	700	2880	4553	1896	2123		1766	3061
BIG052	f	11	Wh. UK	0	0	0	1	1	0	0	0	146.9	32.0	14.8	-1.4354	64	21.6	855	15466	12013	17012	16448	17670	10921	6586
BIG053	f	12	Wh. UK	1	1	1	1	1	1	1	0	148.5	56.0	25.4	2.1094	81	41.4	609	9865	6547	13543	16546			

BIG054	f	11	Wh. UK	1	1	2	1	1	1	1	0	162.5	56.0	21.2	1.3256	84	39.0	772							
BIG055	f	11	Wh. UK	0	0	0	1	0	0	0	0	139	33.0	17.1	-0.1873	53	26.2	769	2187	11890	20812	23334	21509	18622	12481
BIG056	f	11	Blk. Afr	0	0	0	1	0	0	0	0	157.5	50.0	20.2	1.0081	67.5	33.3	689				10103	5867		
BIG057	f	11	Wh. UK	1	1	2	1	1	1	1	0	159.5	44.5	17.5	0.0013	64	23.7	651		10193	8611	11966			
BIG058	f	11	Blk. Car	1	1	1	1	1	1	1	0	153	58.0	24.8	2.1753	89.5	40.8	613			7443	6121	1912		
BIG059	f	12	Blk. Car	0	0	0	1	0	0	0	0	163.5	49.5	18.5	0.1585	57.5	28.4	669	9378	7477	6992	13989	5896	7256	7051
BIG060	f	11	Wh. UK	0	0	0	1	0	0	0	0	147	41.0	19.0	0.6016	69.5	34.7	825	15081	9425	8528	14746	10907	5104	5906
BIG061	f	11	Wh. UK	0	0	0	1	0	0	0	0	148	30.0	13.7	-2.2462	54.5	17.7	883							
BIG062	f	11	Wh. UK	0	0	0	1	0	0	0	0	149.5	80.5	36.0	3.6285	98	54.6	587							
BIG063	f	12	Wh. UK	0	0	0	1	0	0	0	0	156	49.0	20.1	0.7556	66.5	29.1	578							
BIG064	f	11	Bang	0	0	0	1	0	0	0	0	151	40.0	17.5	0.0240	56.5	23.7	671	10513	10831	10244	10400			
BIG065	f	11	Blk. Afr	1	1	2	1	1	1	1	0	167.5	56.5	20.1	1.0023	69	34.4	694	8608	8704	8518	6864	5044		
BIG066	f	11	SA Oth	0	0	0	1	0	0	0	0	150.5	45.0	19.9	0.9140	63.5	32.9	715	19275		9998	11917	16951		
BIG067	f	11	SA Oth	1	1	2	1	1	1	1	0	145	33.0	15.7	-0.9056	63	18.5	725	7995		6157	7727	14779	8985	
BIG068	f	12	Wh. UK	0	0	0	1	0	0	0	0	160	60.0	23.4	1.6867	69.5	39.6	640	12007	6091	11221	13264	12410	7991	
BIG069	f	11	Wh. UK	0	0	2	1	1	0	0	0	149	44.0	19.8	0.8979	69.5	28.3	605			4345	2132			
BIG070	f	12	Wh. UK	1	1	2	1	1	1	0	0	157	51.0	20.7	0.9361	59	30.6	571	11467	12788	20254	12824	13791	9524	1010
BIG071	f	11	Wh. UK	1	1	1	1	1	1	0	0	151	56.0	24.6	2.1318	81.5	42.0	673	9506	16633	14161	10068	9119	11251	6968
BIG072	f	11	SA Oth	0	0	0	1	0	0	0	0	145.5	32.0	15.1	-1.2523	51.5	17.2	750	19456		9971	11907	17955		
BIG073	f	12	SA Oth	1	1	2	1	1	1	0	0	146	43.0	20.2	0.7682	65	27.3	563	3699	14632	14251	25067	16821	7240	6072
BIG074	f	12	Wh. UK	1	1	2	1	1	1	0	0	158.5	43.5	17.3	-0.3686	60	25.5	716			11303	9907	7038	13253	8517
BIG075	f	12	Wh. UK	0	0	0	1	0	0	0	0	162	48.0	18.3	0.0649	58.5	29.3	720	5755	5847	6225	8068	7142	5631	4679
BIG076	f	11	Wh. UK	0	0	0	1	0	0	0	0	150.5	53.5	23.6	1.9324	70.5	40.2	675	3724	4563	6780	1301	6451	10221	1625
BIG077	f	12	SA Oth	1	1	2	1	1	1	0	0	151	43.0	18.9	0.2944	66	32.7	782							
BIG078	f	12	SA Oth	1	1	2	1	1	1	0	0	155	50.5	21.0	1.0380	74.5	36.1	713	10960	11200	9716	9996	11744	10928	14867
BIG079	f	12	SA Oth	0	0	0	1	0	0	0	0	144.5	40.0	19.2	0.4084	69	32.0	749	16650	13498	11095	2312	7801	8196	6636
BIG080	f	12	SA Oth	1	1	2	1	1	1	0	0	136.5	35.0	18.8	0.2654	65.5	29.5	723				2271	10012	12899	10365
BIG081	f	11	SA Oth	1	1	2	1	1	1	0	0	155	51.0	21.2	1.3316	77.5	38.5	770							
BIG082	f	12	SA Oth	0	0	0	1	0	0	0	0	155.5	41.0	17.0	-0.5429	60.5	19.7	616	3741		6897				
BIG083	f	12	Wh. UK	1	1	2	1	1	1	0	0	142.5	27.0	13.3	-2.9490	53		577	5660	6518	6112	5211	8512		
BIG084	f	11	Blk. Afr	0	0	0	1	0	0	0	0	153	88.5	37.8	3.7695	114	57.2	631	4565		8013		4596	8714	
BIG085	f	11	Wh. UK	1	1	2	1	1	1	0	0	161.5	59.0	22.6	1.6993	68.5	38.3	648		11801	9708	7837	7834	6904	3260
BIG086	f	11	Blk. Car	1	1	2	1	1	1	0	0	163	50.0	18.8	0.5441	69	29.1	663	5546	7882			10378	3105	
BIG087	f	11	SA Oth	1	1	2	1	1	1	0	0	149.5	44.0	19.7	0.8535	61	31.4	692	11188	26181	12741			8088	
BIG088	f	12	SA Oth	1	1	2	1	1	1	0	0	143	37.0	18.1	-0.0180	63	30.3	783	26615		13751	8085			
BIG089	f	11	Blk. Car	1	1	1	1	1	1	0	0	166.5	78.0	28.1	2.7513	85	46.8	578	7743		14507	9135	18172	7149	1805
BIG090	f	12	SA Oth	1	1	2	1	1	1	0	0	157.5	48.0	19.3	0.4802	66	31.7	708	14200		12555	3517	8300	8698	11357
BIG091	f	11	Blk. Afr	1	1	2	1	1	1	0	0	155	44.0	18.3	0.3484	60	23.7	592	10541	10345	6121	15534	16431		

BIG092	f	12	Wh. UK	1	1	1	1	1	1	0	0	161.5	63.0	24.2	1.8506	73	40.4	610							
BIG093	f	11	SA Oth	1	1	2	1	1	1	0	0	140	44.0	22.4	1.6568	68	34.7	613	7422	13387	9741	15629	6844	5816	
BIG094	f	11	SA Oth	1	1	1	1	1	1	0	0	161	68.0	26.2	2.4461	82	45.1	651					19496	15288	12763
BIG095	f	11	SA Oth	1	1	2	1	1	1	0	0	164	51.0	19.0	0.5973	66	26.7	577	7436	11780	12839	12976	11217	2914	
BIG096	f	12	SA Oth	1	1	2	1	1	1	0	0	133	24.0	13.6	-2.7191	51	19.2	888	1160	10513	7665	10831	10244	10400	8869
BIG097	f	12	Blk. Afr	1	1	2	1	1	0	0	0	159.5	49.0	19.3	0.4473	60	31.2	697							
BIG098	f	12	SA Oth	1	1	2	1	1	1	0	0	153	49.0	20.9	1.0112	67	33.5	649	11761	4693	5340	14398	10625	4000	8931
BIG099	f	11	SA Oth	1	1	2	1	1	1	0	0	150	43.0	19.1	0.6519	62	29.8	693	7245	9145	11011	10545	11543		
BIG100	f	12	Wh. UK	0	0	0	1	0	0	0	0	162.5	47.0	17.8	-0.1467	61	27.0	698	7845	20111	8948	15446	4600		
BIG101	f	11	SA Oth	0	0	0	1	0	0	0	0	143.5	49.0	23.8	1.9710	77	41.0	699	10996	14437	11389	13141	8745		
BIG102	f	11	SA Oth	0	0	0	1	0	0	0	0	145.5	32.0	15.1	-1.2523	55	22.9	855	15011	18245		14563	13212	22021	
BIG103	f	11	Blk. Car	0	0	0	1	0	0	0	0	160	48.0	18.8	0.5181	59	25.9	592	8223	13208	10753	9341	10928	4262	3994
BIG104	f	12	Blk. Car	1	1	2	1	1	1	0	0	150.5	46.0	20.3	0.8133	66	31.2	640	8679	10770	7958	10412	7261		
BIG105	f	11	SA Oth	1	1	2	1	1	1	0	0	160.5	62.0	24.1	2.0297	79	41.9	674	7293	14468	6088	12403	14192	6455	
BIG106	f	11	SA Oth	1	1	1	1	1	1	0	0	150.5	57.0	25.2	2.2510	81	40.8	599	14940	11444			10631	9879	14424
BIG107	f	12	Blk. Car	0	0	0	1	0	0	0	0	161.5	44.0	16.9	-0.5861	60	20.1	611	21417	10204	12102	11509	6236		
BIG108	f	12	Blk. Afr	0	0	0	1	0	0	0	0	164	46.0	17.1	-0.4707	61	22.2	633			10069	13741	17550	16271	3889
BIG109	f	12	Blk. Car	1	1	1	1	1	1	0	0	162	66.0	25.1	2.0604	71	43.4	650	9383	11620	12757	9550	12173	6099	
BIG110	f	12	SA Oth	1	1	2	1	1	1	0	0	157.5	50.0	20.2	0.7627	63	35.1	743							
BIG111	f	12	SA Oth	1	1	2	1	1	1	0	0	148	51.0	23.3	1.6499	73	41.4	734	17883	15754	19149				
BIG112	f	12	Blk. Afr	0	0	0	1	0	0	0	0	160	54.0	21.1	1.0604	61.5	35.7	684	9549	8432	12909	14303	16543		
BIG113	f	12	Blk. Afr	1	1	1	1	1	1	0	0	170	73.0	25.3	2.0827	73	41.8	543	9183	10406	4162		8222	12093	17694
BIG114	f	11	SA Oth	1	1	1	1	1	1	0	0	158.5	67.5	26.9	2.5535	86	45.4	631		10754	16465	14605	11867	7630	
BIG115	f	12	Wh. UK	1	1	2	1	1	1	0	0	162	62.5	23.8	1.7744	79	42.4	705	14354	14956	9943	6767	10312		
BIG116	f	12	SA Oth	1	1	2	1	1	1	0	0	160.5	54.5	21.2	1.0793	69	36.8	711	15001	11345	10113	16544	9654		
BIG117	f	11	Blk. Afr	1	1	2	1	1	1	0	0	155.5	45.0	18.6	0.4646	72	33.0	803				17451	9254	10488	9218
BIG118	f	12	Wh. UK	1	1	2	1	1	1	0	0	147.5	38.0	17.5	-0.2979	61	24.3	698	8785	12271	12952	13179		10819	4010
BIG119	f	11	Wh. UK	1	1	2	1	1	1	0	0	160.5	44.0	17.1	-0.1869	61	22.1	646							
BIG120	f	11	Blk. Afr	1	1	2	1	1	1	0	0	164.5	60.0	22.2	1.5869	73	37.4	640							
BIG121	f	12	Blk. Afr	1	1	2	1	1	1	0	0	160	49.5	19.3	0.4750	62	34.3	778							
BIG122	f	11	Blk. Afr	1	1	2	1	1	1	0	0	150.5	44.0	19.4	0.7639	60	29.7	667							
BIG123	f	12	SA Oth	1	1	2	1	1	1	0	0	167.5	53.0	18.9	0.3068	59	30.2	673							
BIG124	f	11	SA Oth	1	1	2	1	1	1	0	0	145.5	33.0	15.6	-0.9677	58	22.9	818							
BIG125	f	11	SA Oth	1	1	1	1	1	1	0	0	156.5	62.0	25.3	2.2794	81	42.5	626							
BIG126	f	11	SA Oth	1	1	2	1	1	1	0	0	147.5	50.0	23.0	1.7863	79	42.2	776							
BIG127	f	11	Blk. Afr	1	1	2	1	1	1	0	0	135.5	33.0	18.0	0.2091	63	35.7	889		11056	30823	15001	10811		
BIG128	f	12	Blk. Afr	1	1	2	1	1	0	0	0	154.5	53.0	22.2	1.3758	80	37.7	679							
BIG129	f	11	Wh. UK	1	1	0	1	1	1	0	0	151.5	50.0	21.8	1.4850	69	34.6	626							

BIG130	f	12	Blk. Car	1	1	0	1	1	1	0	0	172.5	57.0	19.2	0.4080	69.5	31.0	654							
BIG131	f	11	SA Oth	1	1	0	1	1	1	0	0	142.5	33.0	16.3	-0.6002	56	20.5	721	16454	8543	17943	16132	17333		
BIG132	f	11	Wh. UK	0	0	0	1	0	0	0	0	151	42.0	18.4	0.3905	67	29.6	740		14200	11464	12500	1517	8300	8698
BIS001	m	11	Blk Afr	1	1	0	1	1	1	0	0	162.5	55.0	20.8	1.5503	63	36.8	730	6956	15598				12915	
BIS002	m	12	Blk Afr	0	0	2	1	1	0	0	0	159	41.0	16.2	-0.6412	63	28.0	871	5067	14958	6932	10220	11432	2934	2544
BIS003	m	12	Blk Afr	1	1	0	1	1	1	0	0	174	62.0	20.5	1.2277	67	37.3	742	9353	1142	12744	12031			
BIS004	m	12	Blk Afr	0	0	0	1	0	0	0	0	156.5	46.4	18.9	0.6887	65	33.2	782							
BIS005	m	11	Blk Afr	1	1	0	1	1	1	1	0	156.5	48.0	19.6	1.1648	66	34.3	764	5768	13600	16966	19095	9499	8039	9546
BIS006	m	12	Blk Afr	0	0	0	1	0	0	0	0	161	54.7	21.1	1.4164	71	37.0	720	1571				1755	7176	6921
BIS007	m	12	Blk Afr	1	1	0	1	1	1	0	0	157	43.6	17.7	0.1469	63	24.2	654				6838	15798	12915	
BIS008	m	12	Bang	1	1	0	1	1	1	0	0	142.5	39.5	19.5	0.8802	65	33.9	774				2132	2510		
BIS009	m	11	Wh. UK	1	1	0	1	1	1	0	0	143	41.0	20.0	1.3142	61	34.8	759	12434	27544	13573	14713	17351		
BIS010	m	12	Blk Afr	0	0	0	1	0	0	0	0	161.5	57.1	21.9	1.6338	72	38.5	709	7449	14500	9345	13372	10368	3914	8456
BIS011	m	11	Blk Afr	1	1	0	1	1	1	0	0	158	46.0	18.4	0.7278	70	33.9	840				2071	10244	12893	10368
BIS012	m	12	Blk Afr	0	0	0	1	0	0	0	0		47.1					497							
BIS013	m	12	Blk Afr	1	1	0	1	1	1	0	0														
BIS014	m	12	Blk Afr	0	0	0	1	0	0	0	0														
BIS015	m	12	Blk Afr	0	0	0	1	0	0	0	0	159	50.1	19.8	1.0097	73	34.9	760	3420	7571	9133	10612	4655		
BIS016	m	12	Wh. UK	1	1	0	1	1	1	0	0	155.5	40.6	16.8	-0.3112	64	25.0	755			8541	10831		10993	5301
BIS017	m	11	Blk Afr	0	0	0	1	0	0	0	0	146	38.1	17.9	0.4929	63	22.3	623							
BIS018	m	12	Blk Afr	0	0	0	1	0	0	0	0	156	50.4	20.7	1.2996	73	36.1	734	10424	17384	16967	9986	10289	6802	
BIS019	m	11	Blk Car	1	1	0	1	1	1	0	0	161	60.5	23.3	2.1647	74	40.6	676	8183	15013		8921		3791	
BIS020	m	11	Blk Car	0	0	0	1	0	0	0	0	156	50.6	20.8	1.5399	71	36.2	731	10258	16168	20894	12170	13055	7387	7528
BIS021	m	12	Wh. UK	1	1	0	1	1	1	0	0	153	40.1	17.1	-0.1300	65	22.2	665							
BIS022	m	11	Blk Car	1	1	0	1	1	1	0	0									10074	4387	6237			
BIS023	m	11	Wh. UK	1	1	0	1	1	1	0	0	135	29.9	16.4	-0.2437	64	29.4	865	19701						
BIS024	m	12	Blk Afr	1	1	0	1	1	1	0	0	169.5	67.5	23.5	2.0135	73	41.5	670			16443	16453	15001	22101	24657
BIS025	m	11	Blk Car	0	0	0	1	0	0	0	0	156	41.5	17.1	0.1032	66	20.8	631	10640	11232		9693			
BIS026	m	11	Blk Afr	1	1	0	1	1	1	0	0	138	33.0	17.3	0.2397	60	26.9	766			16811	13565	15342	13654	18767
BIS027	m	11	Blk Car	0	0	2	1	1	0	0	0	158	50.7	20.3	1.3957	73	35.6	744							
BIS028	m	11	Blk Car	0	0	0	1	0	0	0	0														
BIS029	m	11	Blk Car	1	1	0	1	1	1	0	0								1421			1344			
BIS030	m	11	Blk Afr	1	1	0	1	1	1	0	0	159.5	39.0	15.3	-0.9152	64	20.4	777		14167	9583	12069	13898	1920	
BIS031	m	11	Blk Car								0									21008		4141	15124	6712	9862
BIS032	m	11	Blk Afr	1	1	0	1	1	1	0	0	146	44.0	20.6	1.4960	62	35.6	738	16808	15136	10442	13582	18925		
BIS033	m	11	Blk Car								0											2688		8185	12876
BIS034	m	11	Blk Car	0	0	0	1	0	0	0	0	156	53.5	22.0	1.8578	72	38.0	699			9472	14439	9635		
BIS035	m	11	Blk Car								0														

BIS036	m	11	Wh. UK	0	0	0	1	0	0	0	0	144.5	54.0	25.9	2.6180	68	42.4	625							
BIS037	m	11	Bang	1	1	0	1	1	1	0	0	148	33.0	15.1	-1.1014	62	17.1	750	15443	12124	16788	16431	17321	10332	7011
BIS038	m	11	Blk Afr	0	0	0	1	0	0	0	0	139.5	52.0	26.7	2.7453	62	41.8	576	1156				3895	1484	12176
BIS039	m	11	Wh. UK	1	1	0	1	1	1	0	0	140.5	38.7	19.6	1.1670	65	33.8	763	7791						20931
BIS040	m	11	Wh. UK	0	0	0	1	0	0	0	0	145	38.9	18.5	0.7583	64	32.8	811							
BIS041	m	12	Wh. UK	1	1	0	1	1	1	0	0	146	54.0	25.3	2.3689	63	41.7	630	22328		19810				
BIS042	m	11	Blk Car	0	0	0	1	0	0	0	0	156	41.5	17.1	0.1032	65	21.4	645							
BIS043	m	12	Blk Afr	1	1	0	1	1	1	0	0	144	37.6	18.1	0.3506	63	34.8	878	4451		3392	3976		10523	15657
BIS044	m	11	Turk	1	1	0	1	1	1	0	0										14303	14345	12653	22631	8654
BIS045	m	12	Blk Car	1	1	0	1	1	1	0	0	166.5	70.1	25.3	2.3608	74	43.7	637	6079			16812		6202	10990
BIS046	m	11	Wh. Oth	0	0	0	1	0	0	0	0								8916					13214	12122
BIS047	m	11	Turk	1	1	0	1	1	0	0	0	157	54.3	22.0	1.8690	72	38.1	697			18867	17544	21221	16576	11556
BIS048	m	11	Wh. UK	1	1	0	1	1	1	0	0	145	37.1	17.6	0.3897	63	27.4	754				2030		10065	15388
BIS049	m	11	Wh. UK	0	0	0	1	0	0	0	0								5940	4366	10423	8299	5590		
BIS050	m	12	Blk Afr	1	1	0	1	1	1	0	0	158.5	51.4	20.5	1.2219	73	35.9	742							
BIS051	m	12	Blk Afr	1	1	0	1	1	1	0	0								17678	21356	19760				
BIS052	m	12	Blk Afr	1	1	0	1	1	1	0	0	158	46.0	18.4	0.4777	64	32.9	813			9035	16543	18754	16886	21321
BIS053	m	12	Blk Afr	0	0	0	1	0	0	0	0	158	41.9	16.8	-0.3148	64	24.7	745							
BIS054	m	12	Blk Car	1	1	0	1	1	1	0	0	159	65.6	25.9	2.4723	75	42.9	592	1701	7436			10328	8299	11753
BIS055	m	12	Blk Afr	1	1	0	1	1	1	0	0	147.5	34.7	15.9	-0.8073	63	18.9	710							
BIS056	m	11	Blk Afr	0	0	0	1	0	0	0	0	148	50.3	23.0	2.0847	65	38.9	681	11649	10108		2740	10168		
BIS057	m	12	Blk Afr								0														
BIS058	m	12	Blk Afr	1	1	0	1	1	1	0	0								7743		14507	9135	18172	3149	1805
BIS059	m	12	Blk Afr	1	1	0	1	1	1	0	0	165							23564	17765	16454	11342	11433		7889
BIS060	m	12	Blk Afr	1	1	0	1	1	1	0	0	161	44.0	17.0	-0.2118	65	22.1	654		12323	16876	17543	18465		14321
BIS061	m	11	Blk Afr	1	1	0	1	1	1	0	0	149.5	36.6	16.4	-0.2609	64	20.3	698	24571	18271	23579			19709	13775
BIS062	m	12	Blk Afr								0										13734			4932	
BIS063	m	12	Blk Afr	1	1	0	1	1	1	0	0	157							24666	18199	25459	18209		13799	
BIS064	m	12	Blk Afr	1	1	0	1	1	1	0	0	158	54.2	21.7	1.5859	72	37.9	712	23412	19649	17605		15819	11410	6988
BIS065	m	12	Blk Afr	1	1	0	1	1	1	0	0								9071	16621	18904	17900	20319	8926	7675
BIS066	m	11	Bang	1	1	0	1	1	1	0	0								19649	17605	7085	15819	11410	6988	
BIS067	m	11	Bang	1	1	0	1	1	1	0	0														
BIS068	m	11	Bang	1	1	0	1	1	1	0	0	159	65.0	25.7	2.5944	75	43.5	629	10325	7723			7504	10254	20124
BIS069	m	11	Blk Afr	1	1	0	1	1	1	0	0	155							23627	14768	20953	5459	21174	19160	12799
BIS070	m	11	Bang	0	0	0	1	0	0	0	0	156.5	46.4	18.9	0.9306	64	33.2	782		14666			12254		8326
BIS071	m	11	Bang	1	1	0	1	1	1	0	0								4570	8560	7552				
BIS072	m	11	Bang	1	1	0	1	1	1	0	0	157	67.5	27.4	2.8359	76	44.4	568			9115	16888	14465	16505	

BIS073	m	11	Bang	1	1	0	1	1	1	0	0								11303	9907	1581	7038	13253	8517	5431
BIS074	m	12	Wh. UK								0														
BIS075	m	11	Wh. UK								0	145	37.1	17.6	0.3897	65	26.0	723		12002	12909	13321	15854	11578	
BOW001	m	11	Bang	1	0	0	1	0	0	0	1	144	34.5	16.6	-0.1150	67	20.1	682	12999	14623	14481	14606	12427		
BOW002	m	11	Wh. UK	1	0	0	1	0	0	0	1	152	42.8	18.5	0.7676	72	24.2	597		2189	16243				
BOW003	m	12	Bang	1	0	0	1	1	0	0	1	169	48.6	17.0	-0.1897	68	21.9	612		8434	7465	13204	14854	10511	
BOW004	m	11	SA Oth	1	0	0	1	1	0	0	1	152.5	68.1	29.3	3.0635	84	46.1	543	5978	6814	9221	4351		7072	
BOW005	m	11	Bang	1	0	0	1	1	1	0	1	141.5	29.8	14.9	-1.2353	56	16.5	758		12112		8767	11070		
BOW006	m	11	SA Oth	0	1	0	1	1	1	0	1	154.5	48.3	20.2	1.3725	72	31.2	634		3218	8736				
BOW007	m	11	Bang	1	0	0	1	1	1	0	1	138.5	39.0	20.3	1.4025	72	34.9	744		2700	22438				
BOW008	m	11	SA Oth	1	0	0	1	1	1	0	1	159.5	48.7	19.1	1.0040	72	22.7	467		2808	15040				
BOW009	m	11	Bang	1	0	0	1	0	1	0	1	128	23.4	14.3	-1.7118	56.5	23.4	882		2281	6993				
BOW010	m	12	SA Oth	1	0	0	1	0	1	0	1	142	40.3	20.0	1.0673	72	26.4	567	8159	6336	12063		3328		
BOW011	m	11	Wh. UK	1	0	0	1	0	1	0	1	144	35.4	17.1	0.1127	68	19.4	631		3372	22649				
BOW012	m	11	Wh. UK								1								11436	27144	14221				
BOW013	m	11	SA Oth	0	1	0	1	1	1	0	1	143	35.3	17.3	0.2077	68	25.2	737							
BOW014	m	11	SA Oth	1	0	0	1	0	1	0	1	139	28.3	14.6	-1.4158	56	14.9	751		3711	13888				
BOW015	m	11	Bang	1	0	0	1	0	1	0	1	134.5	25.0	13.8	-2.1192	54	13.1	787	17332	16454	17488	3234	9432		
BOW016	m	11	Bang	1	0	0	1	1	1	0	1	144.5	50.8	24.3	2.3585	84	39.0	609	10751	10332	6092	15717	15936		
BOW017	m	11	Wh. UK	1	0	0	1	1	1	0	1	145	34.1	16.2	-0.3515	67	18.6	685	24651	18249	23959	19709	13775		
BOW018	m	11	Wh. UK	0	1	0	1	1	1	0	1	136.5	31.0	16.6	-0.1150	67	17.4	641	7254	9408	10717	10383	11054		
BOW019	m	12	Bang	1	0	0	1	1	1	0	1	146	36.1	16.9	-0.2326	67.5	24.9	752	9165	9264	9709	8529	10083		
BOW020	m	11	SA Oth	1	0	0	1	0	1	0	1	151.5	36.5	15.9	-0.5418	67	22.2	775		2951	8335				
BOW021	m	11	Wh. UK	1	0	0	1	0	1	0	1	145	34.1	16.2	-0.3515	67	20.4	720	5834	6201	14001	11300	10224		
BOW022	m	11	Bang	0	1	0	1	1	1	0	1	133	35.4	20.0	1.3022	72	28.8	635	1675	10950	9995	9988	8160		
BOW023	m	11	Bang	1	0	0	1	0	1	0	1	158	58.0	23.2	2.1424	83.5	41.3	715	4138	4890	12142	8340			
BOW024	m	12	Bang	0	1	0	1	1	1	0	1	137	28.6	15.2	-1.2878	63	17.2	742	2311	8495		8262	4542		
BOW025	m	11	Wh. UK	0	1	0	1	1	1	0	1	143	34.5	16.9	0.0096	67.5	27.7	815	6710	8218	6238	7712			
BOW026	m	12	SA Oth	1	0	0	1	0	1	1	1	159	48.2	19.1	0.7357	72	23.8	509	6545	7712	8653	13718			
BOW027	m	12	Bang	1	0	0	1	1	0	0	1	147	39.7	18.4	0.4546	71	23.0	598	1768		13346	2644	13255		
BOW028	m	11	Bang	0	1	0	1	1	1	0	1	148	40.1	18.3	0.6788	71	29.5	748	2566	9357	10025	8187	8427		
BOW029	m	11	Bang	1	0	0	1	1	0	0	1	145	36.4	17.3	0.2322	68	20.6	636		17454	10111	10444	9218	8561	
BOW030	m	12	Bang	0	1	0	1	1	1	0	1	156	38.6	15.9	-0.8635	67	21.5	758	2557	19573	9674	11555	4823		
BOW031	m	11	Bang	0	1	0	1	1	1	0	1	158	39.5	15.8	-0.5916	63	14.7	604	3175	9464	11723	10960	6421		
BOW032	m	11	Wh. UK	0	1	0	1	1	1	0	1	149	43.5	19.6	1.1633	72	29.1	644	5840	19496	15288	12763	5685		
BOW033	m	11	Wh. UK	1	0	0	1	1	0	0	1	147	39.3	18.2	0.6284	71	23.4	621	11019	9338	11510	9025	6588		
BOW034	m	11	Wh. Oth	1	0	0	1	1	0	0	1	157	36.8	14.9	-1.2009	57	17.9	767	2681	5834	5228	9229	4330		

BOW035	m	11	SA Oth	1	0	0	1	1	0	0	1	138	36.7	19.3	1.0504	72	32.6	756	3650		13115	18636	11649		
BOW036	m	11	SA Oth	1	0	0	1	1	0	0	1	159	63.1	25.0	2.4707	84	42.5	642	2978	4033	12033	12087	7480		
BOW037	m	11	Oth	1	0	0	1	1	0	0	1	150	50.5	22.4	1.9680	83	36.8	647							
BOW038	m	11	Blk Car	0	1	0	1	1	1	0	1	156	51.8	21.3	1.6776	72	29.6	498	20298	17797	13696	9587			
BOW039	m	11	Bang	1	0	0	1	1	0	0	1	147	60.8	28.1	2.9313	84	47.1	656	12011	13544	13654		23543		
BOW040	m	12	SA Oth	1	0	0	1	1	0	0	1	150	47.8	21.2	1.4571	72	37.6	748	4353	15050	12348	13419	8785		
BOW041	m	11	Bang	1	0	0	1	1	0	0	1	147	39.7	18.4	0.7055	71	29.4	744	3400	2068	626	944	4439		
BOW042	m	11	Wh. UK	0	1	0	1	1	1	0	1	151	38.3	16.8	-0.0293	67.5	18.3	614	4737	14324	9456	8343		12234	14323
BOW043	m	12	Wh. UK	1	0	0	1	1	0	0	1	156	46.4	19.1	0.7359	72	27.6	626	6998	2944	9034	5896	5551		
BOW044	m	11	Bang	1	0	0	1	1	1	0	1	141	33.7	17.0	0.0509	66	25.3	761		6376	10502	19495	14003		
BOW045	m	10	Bang	1	0	0	1	1	0	0	1	148	38.7	17.7	0.6404	68	22.0	629	2100		9623	7283			
BOW046	m	12	SA Oth	1	0	0	1	1	0	0	1	153.5	46.3	19.7	0.9512	73	27.4	580	7793	6975	6681	7651			
BOW047	m	11	Bang	0	0	0	1	1	0	0	1	148	58.4	26.7	2.7369	87	43.3	603	9118	16878	14441	16550			
BOW048	m	11	SA Oth	0	0	0	1	1	0	0	1	143.5	35.2	17.1	0.1238	68	20.9	662		19246		9978		13184	
BOW049	m	11	Bang	1	0	0	1	1	1	0	1	143.5	42.7	20.7	1.5236	68	35.4	730	7288	18660	7763	10650			
BOW050	m	11	Wh. UK	1	1	1	1	1	1	0	1	140	37.8	19.3	1.0556	74	29.9	697	8222	17775	13570	17194			
BOW051	m	11	Bang	0	0	0	1	1	0	1	1	144.5	39.4	18.9	0.9021	64	24.0	587	9747	12035	5800	10342			
BOW052	m	11	Blk Car	1	1	1	1	1	1	0	1	140	40.0	20.4	1.4261	71	31.2	656	22572	11283	8358	11221			
BOW053	m	11	Bang								1								7524	6491	5958	9773			
BOW054	m	11	Bang	1	1	0	1	1	1	1	1	148	49.6	22.6	2.0138	83	41.0	759							
BOW055	m	12	Bang	0	0	0	1	0	0	0	1	156.5	34.8	14.2	-2.1049	58	16.1	803	10793	12778		4897			
BOW056	m	11	Bang	1	0	0	1	1	0	0	1	142.5	31.9	15.7	-0.6635	57	19.7	748	9739	10871	8732	10314			
BOW057	m	11	Bang	1	0	0	1	1	0	0	1	148	40.8	18.6	0.8081	71	31.0	762	10408	15020	11906	12423			
BOW058	m	11	Bang	0	0	0	1	0	0	0	1	146.5	36.8	17.1	0.1502	67	23.9	715	8653	11787	8821	11080			
BOW059	m	11	Bang	1	1	1	1	1	0	0	1	144	36.2	17.5	0.3018	70	17.1	553		15343	11353	10111		15674	9567
BOW060	m	11	Bang	0	0	0	1	1	1	0	1	157.5	38.4	15.5	-0.8136	61	20.8	775	8706	9708	8196	13564			
BOW061	m	12	Wh. UK	0	0	0	1	1	0	0	1	156.5	44.2	18.0	0.3122	70	24.3	625	9813	17186	11055	12632			
BOW062	m	12	Bang	1	1	0	1	1	0	0	1	146.5	47.0	21.9	1.6355	79	36.3	676	27349		15249	11652	17424		
BOW063	m	11	Bang	1	1	0	1	1	1	0	1	143.5	48.9	23.7	2.2472	84	39.9	670	8684	9489	16509	16780			
BOW064	m	12	Bang	0	0	0	1	1	0	0	1	140.5	37.5	19.0	0.7090	61	22.5	556	19728	7982					
BOW065	m	11	Bang	0	0	0	1	0	0	0	1	142	35.8	17.8	0.4393	66	25.6	709	16343	8983	17642	15581	15712		
BOW066	m	11	Bang	1	1	1	1	1	1	0	1	156.5	52.0	21.2	1.6629	78	32.7	592	12909	13152	9818	15854	11578		
BOW067	m	11	Bang	0	0	0	1	1	1	0	1	139.5	50.2	25.8	2.6078	84	43.1	659	8714	6656	10453	10222	10123		
BOW068	m	11	Bang	0	0	0	1	1	0	0	1	142.5	34.9	17.2	0.1704	68	23.4	706		14913	13087				
BOW069	m	12	Bang	1	1	1	1	1	0	0	1	150	42.2	18.8	0.6136	72	25.0	604	11276	10679	14176	16172	14037		
BOW070	m	11	Bang	0	0	0	1	1	1	0	1	142	27.7	13.7	-2.1957	53	19.4	899	9854	9000	6099	8595	9876		
BOW071	m	11	Wh. UK								1	143.5	35.6	17.3	0.2202	68	24.7	723							
BOW072	m	12	Bang								1	141	30.3	15.2	-1.2858	64	22.3	830			10219	12171	9345	12543	13455

BOW073	m	12	SA Oth	1	1	1	1	1	0	0	1	159	46.8	18.5	0.5136	71.5	28.6	688		3384	6112	7377	8994		
BOW074	m	12	SA Oth	1	0	1	1	1	0	0	1	150	59.8	26.6	2.5713	84	43.3	602		9518	9517	9800	9263		
BOW075	m	12	Bang	0	0	0	1	1	1	0	1	148.5	40.3	18.3	0.4128	71	29.0	740	13031	6083	11085	7610	8704		
BOW076	m	11	Bang	0	0	0	1	1	1	0	1	143	44.9	22.0	1.8512	83	40.2	781	10062	10138	17242	16264	14333		
BOW077	m	11	Wh. UK	1	1	0	1	1	0	0	1	143	29.7	14.5	-1.5134	56	18.3	819	4546		9295	5302	5697		
BOW078	m	11	Bang	0	0	0	1	1	0	0	1	145.5	39.7	18.8	0.8573	72	35.2	850		17652	16573	17525		14833	
BOW079	m	11	Bang	0	0	0	1	1	0	0	1	140.5	40.7	20.6	1.4890	72	35.4	739	12338	8536	6046	10438			10633
BOW080	m	11	Bang	1	1	0	1	1	0	0	1	151.5	63.2	27.5	2.8556	84	44.5	584	4766	4372			4765	5350	
BOW081	m	11	Bang								1								9989	8008	12909	14507	16269		
BOW082	m	12	Wh. UK	1	1	0	1	1	0	0	1	151.5	39.9	17.4	-0.0010	66	19.0	574		19965	8268	10578		13683	9242
BOW083	m	12	Bang	1	1	1	1	1	0	0	1	140	28.1	14.3	-1.9941	56	15.3	783	11268	8506	9592	10298			
BOW084	m	11	SA Oth	1	1	1	1	1	1	0	1	157.5	50.2	20.2	1.3733	78	34.4	717	8398	6639	8819	8074			
BOW085	m	11	SA Oth								1														
BOW086	m	11	Bang								1								9698	10967	8842	7929			
BOW087	m	11	Wh. UK	1	1	1	1	1	1	0	1	145.5	35.4	16.7	-0.0697	66	22.8	727							
BOW088	m	11	Bang	0	0	0	1	0	0	0	1	140	27.7	14.1	-1.8393	56	18.2	846	14419	15399	15154	13184			
BOW089	m	11	Bang	0	0	0	1	0	1	0	1	148.5	48.0	21.8	1.8035	81	38.0	730							
BOW090	m	11	SA Oth	0	0	0	1	1	0	0	1	135.5	28.2	15.4	-0.8952	59	18.4	752	21651	14493	13765	24517			
BOW091	m	11	Wh. UK	1	1	1	1	1	1	1	1	132.5	25.1	14.3	-1.6994	57	19.5	840	6569	6722	7074				
BOW092	m	11	Bang	0	0	0	1	0	0	0	1	149	48.2	21.7	1.7893	79	38.1	734	14468	12394	13832	12896			
BOW093	m	12	Bang	0	0	0	1	1	1	0	1	163	63.2	23.8	2.0752	82	37.1	510							
BOW094	m	11	Bang	0	0	0	1	1	1	0	1	142.5	31.2	15.4	-0.8915	64	18.1	748	14988	18429	11981	15148			
BOW095	m	11	Bang	0	0	0	1	1	0	0	1	150.5	47.0	20.8	1.5278	83	38.2	797	8246	9204	7764	8483			
BOW096	m	11	Bang	1	1	0	1	1	0	0	1	153	45.0	19.2	1.0333	71	28.9	655	9840	17680	12994	9297			
BOW097	m	12	Wh. UK	1	1	1	1	1	1	0	1	158.5	48.7	19.4	0.8558	72	29.2	632	10766	16088	6173	6246			
BOW098	m	11	Bang	0	0	0	1	0	0	0	1	144	33.2	16.0	-0.4755	59	23.4	795	6941	7159	6454	7491			
BOW099	m	11	SA Oth	0	0	0	1	1	0	0	1	135	27.2	14.9	-1.2046	54	16.6	755	11604	10691	14051	13117			
BOW100	m	11	Bang	0	0	0	1	1	1	0	1	144	42.3	20.4	1.4234	76	31.5	655	10199	10849	8379	8773			
BOW101	m	11	Bang	0	1	1	1	1	0	0	1	148	59.3	27.1	2.7941	88	44.7	628	13795		4216	10019			
BOW102	m	11	Bang	0	0	0	1	1	0	0	1	151	56.6	24.8	2.4472	86	43.7	712							
MOR001	f	12	Bang	1	1	0	1	1	1	0	0	143	32.1	15.7	-1.2261	63	19.5	745						15984	13253
MOR002	f	12	Bang	1	1	0	1	1	1	0	0	155	52.8	22.0	1.3144	72	37.9	700	13840	15024	10998	8666	5999		
MOR003	f	12	Bang	1	1	0	1	0	1	0	0	165	49.7	18.3	0.0504	71	27.7	667	5455	5948	5927				
MOR004	f	12	Bang	0	1	1	1	1	1	0	0	149	32.4	14.6	-1.9375	58	16.7	785	5361			1252	9429	19367	14621
MOR005	m	12	Bang	1	1	0	1	1	1	0	0	149	26.6	12.0	-4.5840	58		729	15971				12485		8299
MOR006	f	12	Wh. UK								0	157	52.8	21.4	1.1572	71	37.3	717							
MOR007	m	12	Bang	0	1	0	1	1	1	1	0	142	30.9	15.3	-1.2260	61	18.7	761							
MOR008	m	12	Wh. UK	1	1	2	1	1	1	1	0	148	44.5	20.3	1.1760	82	31.1	644		5973		8118	8379	21345	

MOR009	m	12	Bang	1	1	0	1	1	1	0	0	153	39.4	16.8	-0.2891	64	19.6	633	11849	10000		2522	10433		
MOR010	m	12	SA Oth	1	1	0	1	1	1	0	0	145	30.4	14.5	-1.8911	59	9.6	673	5455	5948	5927	7033			
MOR011	f	12	Bang								0	143	30.9	15.1	-1.5895	62	16.7	743		15011	12342	12121	16043	12344	
MOR012	f	12	Bang	1	1	0	1	1	1	0	0	153	62.0	26.5	2.3143	75	43.2	591	14758	11554		14443	15169	15378	14235
MOR013	m	12	Bang								0	145	47.5	22.6	1.8089	73	38.1	687							
MOR014	f	12	Bang	1	1	0	1	0	0	1	0	146	47.2	22.1	1.3595	73	37.5	694							
MOR015	f	12	Bang	1	1	1	1	1	1	1	0	152	40.0	17.3	-0.3697	69	23.1	674	9566	14477	9483	13298			
MOR016	f	12	Bang	1	1	1	1	1	1	1	0	149	50.5	22.7	1.5174	85	36.8	630	5733	5274		6998	6361		
MOR017	f	12	Bang	0	0	0	1	1	0	0	0	162	44.0	16.8	-0.6387	69	30.4	882	5526	5327		4833	3228		1846
MOR018	f	12	Bang	0	1	0	1	1	0	1	0	145	30.4	14.5	-2.0330	56	15.0	768	9969	13741	15184		16912	16271	3889
MOR019	m	12	SA Oth	1	1	0	1	1	1	0	0	150	60.0	26.7	2.5848	75	43.0	585		11263	9460	11800	12129		
MOR020	m	12	Wh. Oth	1	1	0	1	1	1	0	0	153	59.1	25.2	2.3538	74	42.7	648	3005		2044	4075	19560	12695	2660
MOR021	m	12	SA Oth	0	0	0	1	1	1	0	0	141	39.7	20.0	1.0614	71	27.0	586	6748	7182	6358				
MOR022	m	12	Blk Car	1	1	0	1	0	0	1	0	146	28.4	13.3	-2.9525	57	8.1	756			21544	15633	14334	25132	
MOR023	m	12	Bang	1	1	0	1	1	1	1	0	148	33.4	15.2	-1.2802	66	19.7	785	7911	5901		5183	5661		
MOR024	f	12	Bang	1	1	0	1	1	1	0	0	155	54.7	22.8	1.5228	73	39.2	687	9445	6263	5627	9602	6408		
MOR025	m	12	Bang	0	1	0	1	1	1	1	0	152	41.1	17.8	0.1944	69	22.4	616	18929	17372	2756	21133	16577	8885	11543
MOR026	m	12	Wh. UK	1	2	2	1	1	1	0	0	146	48.0	22.5	1.7911	73	38.1	688	9513	14085		1748	1454	13823	5559
MOR027	m	12	Wh. UK	1	1	0	1	0	1	1	0	132	57.5	33.0	3.2964	79	60.0	905	21611	18325		7712	18295	1558	17373
MOR028	m	12	Wh. UK	0	1	0	1	0	1	0	0	150	39.4	17.5	0.0617	65	24.2	687	8527		10587	14549		7819	13994
MOR029	m	12	Bang								0	136	28.0	15.1	-1.3600	62.5	18.8	775	14324	9133	18354	14654	16449		
MOR030	f	12	Bang	1	1	1	1	1	1	1	0	160	66.8	26.1	2.2430	95	44.0	621	5983	4141	4284	7820	4731		
MOR031	m	12	Bang	1	2	2	1	1	1	0	0	152	48.0	20.8	1.3196	71	36.0	733	15969	12554	13333	8555		1286	1338
MOR032	f	12	Bang	0	0	0	1	1	0	0	0	154	42.4	17.9	-0.1116	72	25.2	669	6372			1874	6125		
MOR033	f	12	Bang								0	153	41.9	17.9	-0.1024	63	34.3	889		11392	10504	11169	7806		12294
MOR034	f	12	Bang								0	151	53.5	23.5	1.6929	75	39.8	671							
MOR035	f	12	Bang	1	1	1	1	1	2	1	0	141	30.9	15.5	-1.3191	61	20.1	770			14212	16432		16284	13853
MOR036	m	12	Bang	1	1	1	1	1	2	1	0	131	51.0	29.7	2.9805	85	48.2	643							
MOR037	m	12	Bang	1	2	2	1	1	1	0	0	140	28.4	14.5	-1.8654	59	13.6	743	13724	17655	11163	3894			
MOR038	f	12	Bang	1	2	2	1	1	1	0	0	147	47.2	21.8	1.2773	72	37.4	709		1478			23368		6582
MOR039	f	12	Bang	0	0	0	1	1	0	0	0	143	44.0	21.5	1.1851	72	36.7	715			7899	5169			
MOR040	m	12	Bang	0	1	1	1	1	1	0	0	163	58.1	21.9	1.6273	85	33.2	527	7755	2442	7549	7879			
MOR041	m	12	Blk Afr.	1	2	2	1	1	1	0	0	151	48.8	21.4	1.5016	71	36.9	717	7983	15211		8711			3799
MOR042	m	12	Bang	1	2	2	1	1	2	0	0	143	37.9	18.5	0.5228	64	32.7	807	24941			21378	2921	6229	11153
MOR043	f	12	Bang	1	1	0	1	1	0	0	0	164	48.7	18.1	-0.0125	67	31.1	779			7364	1148			
MOR044	m	12	Blk Afr	1	2	2	1	1	1	0	0	155	64.2	26.7	2.5931	75	43.2	572							
MOR045	f	12	Bang	1	1	0	1	1	1	0	0	155	46.3	19.3	0.4513	71	27.9	619							

MOR046	m	12	Bang								0	134	37.6	20.9	1.3688	71	35.5	723	24941			21378			6229
MOR047	m	12	Bang	0	0	0	1	1	1	0	0	146	32.5	15.2	-1.2814	61	15.8	713				6838	15798	12915	2129
MOR048	m	12	Bang	1	1	0	1	1	0	1	0	141	29.9	15.0	-1.4332	59	14.1	705			11222	11157	11744	6328	21775
MOR049	f	12	Wh. UK	1	1	0	1	1	0	1	0	145	36.3	17.3	-0.3925	67	28.2	797	14261	16543	17321	12848			
MOR050	f	12	Blk. Afr	0	0	0	1	1	0	0	0	148	42.3	19.3	0.4660	65	33.7	779	3513		12262				
MOR051	m	12	Bang	1	2	2	1	1	2	0	0	156	41.5	17.1	-0.1704	64	21.1	638		4226		13724	17655	11163	3894
MOR052	f	12	Bang	1	1	0	1	1	1	0	0	150	37.7	16.8	-0.6439	64	23.8	739	11243	10193	9677		3400	4678	8109
MOR053	f	12	Bang	0	0	0	1	1	1	0	0	149	32.6	14.7	-1.8748	59	15.0	745	21003	16034				12170	13081
MOR054	m	12	Bang	1	2	2	1	1	2	0	0	144	37.3	18.0	0.2858	63	34.4	880		9893	8233	9183			
MOR055	m	12	Bang								0	147	39.3	18.2	0.3744	63	33.6	851	11322	10654	14046	16433		14037	
MOR056	m	12	Bang	0	0	0	1	1	0	0	0	167	53.9	19.3	0.8342	88	31.0	660							
MOR057	f	12	Bang	1	2	2	1	1	1	0	0	152	54.1	23.4	1.6815	75	39.9	674							
MOR058	m	12	Bang	0	0	0	1	1	0	0	0	151	34.4	15.1	-1.3978	59	14.2	687	7391	1288	2657		9957		1622
MOR059	f	12	Bang	0	0	0	0	0	0	0	0	151	52.0	22.8	1.5324	90	38.8	682	14984	1579	15858	1549	1374		
MOR060	m	12	Bang	0	0	0	1	1	0	0	0	161	38.5	14.9	-1.5750	59	21.3	843	10221	13422	15365		17012	16567	4133
MOR061	m	12	Bang	1	2	2	1	1	1	0	0	134	38.7	21.6	1.5430	72	36.5	713							
MOR062	m	12	Bang	0	0	0	1	1	0	0	0	146	50.9	23.9	2.0941	74	40.2	667	1841	1675	15754	19149	2993	2299	17883
MOR063	m	12	Blk Afr.	0	0	0	1	1	1	0	0	154	44.0	18.6	0.5307	83	29.0	709	9925	9113		9341		4429	
MOR064	f	12	Bang	1	1	1	1	1	1	1	0	152	42.6	18.4	0.1264	64	24.2	604							
MOR065	f	12	Bang	0	0	0	1	0	1	0	0	151	40.4	17.7	-0.1826	74	25.1	687	9383	1162	12757		12173		
MOR066	m	12	Bang	0	1	0	1	0	0	0	0	149	35.8	16.1	-0.6975	62	17.2	657		5812	5556	6252	7886		
MOR067	f	12	Bang	1	1	0	1	1	1	0	0	156	53.5	22.0	1.3163	82	44.4	896							
MOR068	m	12	Wh. UK	0	0	0	1	1	0	0	0	153	34.5	14.7	-1.6647	59	17.2	777							
MOR069	f	12	Wh. UK	0	0	0	1	1	0	0	0	152	32.6	14.1	-2.2898	59	15.4	804	5989	5891			5227	3688	5789
MOR070	m	12	Bang	0	0	0	1	1	0	0	0	150	55.8	24.8	2.2734	74	41.8	655	11649				1168		
MOR071	f	12	Bang	0	0	0	1	1	0	0	0	141	47.4	23.8	1.7805	60	44.0	780	10702	10064	7364	11048			
MOR072	m	12	Wh. UK	1	2	2	1	1	1	0	0	142	50.5	25.0	2.3179	74	41.6	651			5194	7785	12143		
MOR073	m	12	Bang	0	0	0	1	1	0	0	0	166	47.5	17.2	-0.0748	69	25.3	694	9860	8942	8053	14950			
MOR074	f	12	Wh. UK	0	0	0	1	1	0	0	0	161	44.8	17.3	-0.3838	66	23.5	659			15841	13024	10998	8666	5889
MOR075	f	12	Bang	0	0	0	1	1	0	0	0	159	41.9	16.6	-0.7379	64		x			7629			7542	1471
MOR076	f	12	Bang	1	1	0	1	1	1	0	0	151	33.0	14.5	-2.0230	75	11.9	704		9589				3834	3455
MOR077	f	12	Wh. UK	1	2	2	1	1	1	0	0	150	50.5	22.4	1.4396	73	38.2	689	6539			1593	7671	2436	3292
MOR078	m	12	Wh. UK	0	0	0	1	1	0	0	0	154	55.4	23.4	1.9843	75	40.0	675		13199	2634	13881			
MOR079	f	12	Bang	0	0	0	1	1	0	0	0	154	33.0	13.9	-2.4401	59	9.2	703	12111	13211	13844	9344	23944		
MOR080	f	12	Bang	1	2	2	1	1	1	0	0	149	27.4	12.3	-3.8506	59	2.5	765		3799		3749	1181	1183	3591
MOR081	f	12	Wh. UK	0	0	0	1	1	0	0	0	160.5	44.8	17.4	-0.3329	66		x	6838	15798	12915	21029			
MOR082	m	12	Wh. UK	1	2	1	1	1	2	0	0	148	40.7	18.6	0.5424	64	32.6	801			8757		9813		
MOR083	f	12	Wh. UK	0	0	0	1	1	0	0	0	128	38.2	23.3	1.6576	74	41.9	743	15977			8296	12479		

MOR084	f	12	Wh. UK	0	0	0	1	1	0	0	0	151	47.9	21.0	1.0344	71	36.1	721		2816	11089		2149		
MOR085	f	12	Wh. UK	0	0	0	1	1	0	0	0	121	52.0	35.5	3.4720	85	60.3	811	23412	19649	17605	7085	15819	11410	6988
MOR086	f	12	Wh. UK	1	1	0	1	1	1	0	0	152	39.5	17.1	-0.4737	65		x	14984	15079	15858	15409	13704	7290	8890
MOR087	m	12	Wh. UK	0	0	0	1	1	0	0	0	162	54.7	20.8	1.3398	71	36.6	723	7813	9029				9127	4398
MOR088	m	12	Wh. UK	1	1	0	1	1	1	0	0	135	27.7	15.2	-1.3159	63	15.3	714			9343	11674	12575	9587	12342
MOR089	m	12	Wh. UK	0	0	0	1	1	0	0	0	147	59.9	27.7	2.7352	76	43.8	565	9731	9584	8578	11336	9285		
MOR090	m	12	Wh. UK	0	0	0	1	1	0	0	0	156	74.2	30.5	3.0633	77	49.3	592							
MOR091	f	12	Wh. UK	0	0	0	1	1	1	0	0	140	39.0	19.9	0.6751	80	32.9	725	10330	10020	5721	8817	12294	14667	7469
MOR092	m	12	Wh. UK	0	0	0	1	1	0	0	0	159	51.4	20.3	1.1810	82	29.1	548	14301			8100	14206	2489	
MOR093	f	12	Wh. UK	0	0	0	1	1	0	0	0	167	34.6	12.4	-3.7846	72	6.2	793		9589		1705		3834	3455
MOR094	m	12	Wh. UK	0	0	0	0	1	0	0	0	159	49.2	19.5	0.8836	65	34.3	768	8541	10831	20452	10993	5301		
MOR095	f	12	Bang	1	1	0	1	0	1	0	0	157	45.0	18.3	0.0509	77	26.4	660	6539	4530	3340	10593	7671	2436	3292
MOR096	m	12	Bang	0	1	0	1	1	1	0	0	147	30.9	14.3	-2.0259	65	19.7	865	14166	14741	2546	4033	9781	6706	10251
MOR097	f	12	Bang	0	0	0	1	1	0	0	0	144	57.0	27.5	2.4863	86	47.4	703							
MOR098	m	12	Bang	1	1	0	1	1	1	0	0	139	36.3	18.8	0.6266	64	32.5	784	17454	9605	9218	8562			
MOR099	m	12	Bang	1	1	0	1	1	1	0	0	153	44.8	19.1	0.7633	65	33.5	780							
MOR100	m	12	Wh. UK	0	0	0	0	1	0	0	0	136	30.0	16.2	-0.6400	62	21.2	737	18011	6421		19543	20234	13134	
MOR101	m	12	Bang	1	1	0	1	1	1	0	0	169	71.4	25.0	2.3097	74	43.9	654							
MOR102	f	12	Bang	0	0	0	1	1	1	0	0	141	26.2	13.2	-3.0524	67	8.2	772		13134	19676	10645	19111		
MOR103	f	12	Wh. UK	1	1	0	1	1	1	0	0	157	43.6	17.7	-0.1962	63	26.5	712							
MOR104	f	12	Bang	0	0	0	1	1	1	0	0	154	62.1	26.2	2.2598	94	42.9	598							
MOR105	f	12	Wh. UK	0	0	0	1	1	0	0	0	148	60.1	27.4	2.4780	90	45.0	617							
MOR106	f	12	Bang	1	1	0	1	1	1	0	0	148	36.3	16.6	-0.7387	64		x		1569	17454	9602	10444	9218	8561
MOR107	m	12	Bang	1	1	0	1	1	1	0	0	149	50.9	22.9	1.8874	81	38.7	675							
MOR108	f	12	Wh. UK	1	1	0	1	1	1	0	0	145	47.9	22.8	1.5264	74	38.6	687							
MOR109	m	12	Blk Afr	1	1	0	1	1	1	0	0	148	31.6	14.4	-1.9181	61	16.5	796	7424		17306		20387	16124	15672
MOR110	f	12	Bang	0	0	0	1	1	1	0	0	150	34.6	15.4	-1.4202	68	17.2	722				11907	16955		
MOR111	f	12	Bang	1	1	0	1	1	1	0	0	143	34.6	16.9	-0.5608	66	20.4	666							
MOR112	m	12	Wh. Oth	0	0	0	1	1	1	0	0	142	36.4	18.1	0.3146	64	21.6	605	10033	12543	8145	12443	11954	8122	
MOR113	m	12	Bang	0	0	0	1	0	0	0	0	153	43.5	18.6	0.5430	74	27.4	669							
MOR114	m	12	Bang	0	0	0	1	1	0	0	0	160	59.9	23.4	1.9928	85	42.6	744							
MOR115	f	12	Wh. UK	0	0	0	1	1	1	0	0	145	34.5	16.4	-0.8251	68	21.2	719							
MOR116	m	12	Bang	0	0	0	1	1	0	0	0	140	33.6	17.1	-0.1234	63	19.3	632			12473	13562	5622	8995	
MOR117	m	12	Bang	1	1	1	1	1	2	1	0	142	29.8	14.8	-1.6326	61	15.6	752							
MOR118	f	12	Bang	0	0	0	1	1	0	0	0	130	24.5	14.5	-2.0059	59	21.6	850	12909	13152	9818	15854	11578	8681	
MOR119	f	12	Bang	0	0	0	1	1	0	0	0	154	53.2	22.4	1.4363	79	39.5	722							
MOR120	m	12	Bang	0	0	0	1	1	1	1	0	146	30.0	14.1	-2.2242	59	17.5	845							

MOR121	m	12	Bang	0	0	0	1	1	0	1	0	156	42.7	17.5	0.0786	62	23.6	654							
MOR122	m	12	Bang	0	0	0	1	1	1	0	0	144	52.8	25.5	2.3913	74	44.8	721							
MOR123	m	12	Wh. UK	0	0	0	1	1	1	1	0							601							
MOR124	m	12	Wh. UK	1	1	1	1	1	2	1	0	157	67.5	27.4	2.6890	76	44.6	575							
MOR125	m	12	Blk Afr	1	1	0	1	1	1	1	0	150	51.5	22.9	1.8787	74	45.6	881							
MOR126	m	12	Blk Afr	1	1	0	1	0	1	0	0	143	46.8	22.9	1.8780	74	36.5	629							
MOR127	f	12	Bang	0	0	0	1	1	0	0	0							619							
MOR128	m	12	Blk Afr.	0	0	0	1	1	0	0	0	146	37.6	17.6	0.1236	63	30.1	811			17272	16385	17597		
MOR129	f	12	Bang	0	0	0	1	1	0	0	0	142	33.5	16.6	-0.7170	64	27.1	820	16743	15345	10345	13833	18564		
MOR130	f	12	Bang	0	0	0	1	1	1	1	0	134	38.2	21.3	1.1143	71	42.1	850							
MOR131	f	12	Blk. Car	0	0	0	1	1	0	0	0	159	60.5	23.9	1.8007	74	47.4	878							
MOR132	f	12	Bang	0	0	0	1	1	1	1	0	151	53.6	23.5	1.7032	73	36.6	570							
MOR133	f	12	Bang	1	1	0	1	1	0	1	0	143	51.4	25.1	2.0578	74	45.1	748							
MOR134	f	12	Wh. UK	0	0	0	1	1	1	1	0	150	53.6	23.8	1.7761	73	43.5	763							
MOR135	f	12	Bang	1	1	1	1	1	2	1	0	151	47.4	20.8	0.9669	71	37.7	780							
MOR136	f	12	Bang	0	0	0	1	1	0	0	0	155	47.2	19.6	0.5871	66	35.7	800							
MOR137	f	12	Bang	0	0	0	1	1	1	0	0	148	56.1	25.6	2.1518	74	44.3	694							
MOR138	f	12	Bang	0	0	0	1	1	0	0	0							733							
MOR139	f	12	Blk. Afr	0	0	0	1	1	0	0	0	143	57.7	28.2	2.6024	76	51.1	794							
MOR140	m	12	Wh. UK	1	1	1	1	1	1	1	0	130	23.2	13.7	-2.5462	59	37.8	1116							
MOR141	m	12	Wh. UK	0	0	0	1	0	1	0	0	150	57.6	25.6	2.4146	74	43.3	656							
MOR142	m	12	Wh. UK	0	0	0	1	0	1	0	0	155	60.1	25.0	2.3127	74	46.2	779							
MOR143	m	12	Bang	0	0	0	1	1	0	0	0	156	50.4	20.7	1.2996	73	36.1	734							
MOR144	f	12	Bang	0	0	0	1	1	0	0	0	166	55.6	20.2	0.7697	73	36.3	758							
MOR145	m	12	Bang	0	0	0	1	1	0	0	0	154	61.0	25.7	2.4349	75	43.0	629							
MOR146	m	12	Bang	0	0	0	1	1	0	0	0	148	36.5	16.7	-0.3816	64	23.6	745	15166	10530	8245	7987	10760	7885	
MOR147	m	12	Wh. UK	0	0	0	1	1	0	0	0	158	50.6	20.3	1.1609	73	35.7	750							
MOR148	f	12	Turk	1	1	0	1	1	1	0	0	157													
MOR149	m	12	Bang	0	0	0	1	0	0	0	0														
MOR150	f	12	Bang	0	0	0	1	0	0	0	0														
MOR151	m	12	Blk Afr.	0	0	0	1	0	0	0	0														
MOR152	m	12	Wh. UK	0	0	0	1	1	0	0	0														
OAK001	m	11	Bang	0	0	0	1	1	0	1	1	159	65.0	25.7	2.5944	93	44.3	658		10916	16546	14802	11803	7937	
OAK002	m	11	Bang	0	0	0	1	1	1	0	1	147	42.4	19.6	1.1728	74	34.1	768	2131	6099	10105	8892			
OAK003	m	11	SA Oth	1	1	0	1	1	1	0	1	156	42.7	17.5	0.3434	62.5	24.4	674		2414	5659	7507	7125		
OAK004	m	11	Bang	0	0	0	1	1	2	0	1	150	48.1	21.4	1.7024	70	29.0	502							
OAK005	f	12	Wh. UK	0	0	0	1	1	0	0	1														
OAK006	m	11	Turk	1	1	0	1	0	0	1	1	153	62.3	26.6	2.7300	97	43.3	587	10509	9453	14380	10417	9252		

OAK007	f	11	Bang	1	1	2	1	1	2	0	1	145	34.9	16.6	-0.4209	68	25.2	784	10119	11173	9479	8126	9447	12368	15137
OAK008	f	11	Bang	1	1	1	1	1	1	0	1	147	33.3	15.4	-1.0724	62	18.9	755	10175	10363	5613	7639	4425		
OAK009	m	11	Blk Afr.	0	0	0	1	1	1	1	1	147	35.6	16.5	-0.2051	71	28.0	852							
OAK010	f	11	Wh. Oth	0	0	0	1	1	0	0	1	160	49.6	19.4	0.7461	65	34.4	776	17220	9572	9465	12286	18797		
OAK011	f	11	Wh. UK	0	0	0	1	1	0	0	1	157	50.6	20.5	1.1248	73	35.9	740			9045	6532	5296		
OAK012	f	11	Wh. UK	0	0	0	1	1	0	0	1														
OAK013	f	11	Wh. UK	0	0	0	1	0	0	0	1	156	74.2	30.5	3.0685	76	47.1	501		9302	6918	5560	9603	2615	2324
OAK014	f	11	Wh. UK	0	0	0	1	1	0	0	1	156.5	45.0	18.4	0.3719	64		x	3886	4500	9217	10407	10150	5358	4564
OAK015	f	11	Wh. UK	0	0	0	1	1	0	0	1	160	43.5	17.0	-0.2287	65		x	15422	13433	11323	12176	17544		
OAK016	f	12	Bang	1	1	0	1	1	1	0	1	157	54.7	22.2	1.3726	73	38.3	693	4691	1657	10996	14437	11389		
OAK017	f	12	Bang	0	0	0	1	1	0	0	1	159	49.2	19.5	0.5208	65		x	11497	10187	9935	13964	10217		
OAK018	f	12	Bang	0	0	0	1	1	0	0	1	159	39.0	15.4	-1.3900	63		x	13147	9229	19787	10446	18877		1365
OAK019	f	12	Bang	0	0	0	1	1	0	0	1	158	50.6	20.3	0.8003	73	35.6	748	8605	8558	11038	9487	9331	12580	4723
OAK020	f	11	Bang	0	0	0	1	1	0	0	1								3422	7569	9913	9723			
OAK021	f	12	Bang	1	1	0	1	1	1	0	1	156	48.0	19.7	0.6145	66	34.6	762	7436	6856	5064	5886	6578		
OAK022	f	11	Bang	0	0	0	1	1	0	0	1									10853	6785	11918	8679		
OAK023	f	11	Bang	0	0	0	1	1	0	0	1	157	52.8	21.4	1.3858	71	37.3	715	13263	10691	7884	8050	6495	6670	3086
OAK024	f	12	Bang	1	1	0	1	1	1	0	1	157	54.3	22.0	1.3287	72	38.0	694		2627	17059				1734
OAK025	m	11	SA Oth	1	1	1	1	1	1	1	1	154	86.5	36.5	3.6397	107	52.4	445							
OAK026	m	11	SA Oth	0	1	0	1	1	0	1	1	156	44.6	18.3	0.6869	77	27.4	682	8527		10587	14549	7819	5509	
OAK027	m	11	Bang	0	0	0	1	1	1	0	1	146	51.6	24.2	2.3358	86	41.1	676		19965	8268	10578	13683		
OAK028	m	11	Bang	1	1	2	1	1	1	1	1	139	31.2	16.1	-0.3931	62	19.5	713	16512		17642	15581	15712	10979	
OAK029	m	11	Bang	0	0	0	1	0	0	0	1	157	46.4	18.8	0.8849	76	25.7	590	8732	6999	13720	16999			11517
OAK030	m	11	Blk Afr	0	1	0	1	0	1	0	1	142	33.4	16.6	-0.1553	59	19.8	684			16249	16833			
OAK031	m	11	Bang	0	1	1	1	1	2	1	1	140	34.9	17.8	0.4626	72	24.9	694	12999	14623	14481	14606	12427	8425	15686
OAK032	m	11	Bang	0	0	0	1	1	0	1	1	150	49.5	22.0	1.8618	78	35.7	646	8112	7967	13407	14651	10517		
OAK033	m	11	Blk Afr	0	1	0	1	1	1	1	1	154	41.5	17.5	0.3212	76	28.5	782	5878	6719	8221	5354	7072		
OAK034	m	11	Turk	1	1	2	1	1	1	0	1	147	44.0	20.4	1.4119	75	30.5	627		12112		8767	11070	11254	
OAK035	m	11	Bang	0	0	0	1	1	0	1	1	147	34.8	16.1	-0.4191	69	17.9	677	8159	6336	12063		3328	8355	
OAK036	m	11	Bang	0	0	0	1	1	0	0	1	140	30.3	15.5	-0.8276	59	17.3	726			11131	26181	12741	8085	
OAK037	m	11	Bang	0	1	1	1	0	2	1	1	157	50.6	20.5	1.4623	77	35.2	717	17263	16385	17597	2499	9762		
OAK038	m	11	Bang	0	2	0	1	1	1	0	1	153	65.6	28.0	2.9174	94	44.0	531	10751	10332	6092	15717	15936	10036	7747
OAK039	m	11	Bang	1	1	2	1	1	1	0	1	153	54.7	23.4	2.1703	81	36.6	572	24651	18249	23959	19709	13775	6462	5849
OAK040	m	11	Bang	1	1	1	1	1	2	1	1	145	35.5	16.9	0.0166	65	23.5	728	7254	9408	10717	10383	11054	5668	5539
OAK041	m	11	Bang	0	0	0	1	0	1	0	1	144	39.7	19.1	1.0050	72	31.1	730	9165	9264	9709	8529	10083		1952
OAK042	m	11	Bang	0	0	0	1	0	0	0	1	152	64.8	28.0	2.9203	93	47.2	653	5944	6309	12830	11305	10112		
OAK043	m	11	Bang	0	0	0	1	1	0	0	1	134	34.6	19.3	1.0498	67	31.8	740			19543		9878	11707	16955

OAK044	m	11	Bang	0	0	0	1	0	0	0	1	147	55.9	25.9	2.6191	88	41.2	581		6710	8218	6238			
OAK045	m	11	Blk Car	0	1	0	1	0	0	1	1	158	67.3	27.0	2.7785	90	44.2	581	6545	7712	8653	13718			1027
OAK046	m	11	Bang	0	0	0	1	1	1	1	1	142	34.0	16.9	0.0046	68	24.0	742	10911	7546	4354	13454	15445	16544	12234
OAK047	m	11	Bang	0	0	0	1	1	1	0	1	162	57.1	21.8	1.8012	89	38.0	701	11019	9338	11510	9025	6588		2863
OAK048	m	11	Bang	1	1	1	1	1	1	1	1	155	57.9	24.1	2.3156	86	41.9	689							
OAK049	m	11	SA Oth	0	0	0	1	1	0	0	1	151	47.6	20.9	1.5640	77	32.7	639	12091	13320	13725	9488	23293		
OAK050	m	11	Bang	1	1	0	1	1	1	1	1	155	50.2	20.9	1.5694	76	37.1	750							
OAK051	f	11	Bang	1	1	0	1	1	1	0	1	150	36.5	16.2	-0.6155	63	23.7	782	6998	2944	9034	5896	5551	8028	2972
OAK052	m	11	SA Oth	1	1	0	1	1	1	0	1	161	38.5	14.9	-1.2582	60	23.9	901		6376	10502	19495	14003	23076	11895
OAK053	f	11	Wh. UK	0	0	0	1	1	0	0	1	141	37.1	18.7	0.4842	74	28.9	717	8705	8579	9027	6914	7843	8993	6324
OAK054	f	11	Bang								1														
OAK055	f	11	Bang								1														
OAK056	f	11	Wh. UK	1	1	1	1	1	0	1	1	144	36.1	17.4	-0.0357	74	25.3	726	2207	9319	6996	1883	7004	5900	5461
OAK057	f	11	Wh. UK	0	0	0	1	1	1	0	1	147	39.8	18.4	0.3897	69	29.3	738	2221	9718	7424	10333	10350		4018
OAK058	f	11	Bang	0	0	0	1	0	1	0	1	147	45.4	21.0	1.2688	80	37.2	756	8633	17410	11268	6141	7118		
OAK059	f	11	Bang	1	1	2	1	1	2	1	1	141	44.8	22.5	1.6780	79	40.7	762	6958	4188	8252	8584	9520		
OAK060	f	11	Wh. UK	0	1	1	1	1	1	1	1	158	54.7	21.9	1.5188	90	40.6	782	11173	7919	5121	7726	7047		
OAK061	m	11	SA Oth	0	0	0	1	1	0	0	1	142	29.8	14.8	-1.3142	58	18.5	801	13011	12012	15445	13211	8541	2611	10554
OAK062	m	11	Bang	0	0	0	1	1	0	0	1	141	30.6	15.4	-0.8732	61	17.1	729	28738	6864	19835	22785	19012	11614	22882
OAK063	m	11	Bang	0	0	0	1	1	1	0	1	138	28.7	15.1	-1.0980	59	11.5	662	19246		9978	11907	16955		
OAK064	f	11	Bang	0	0	0	1	1	0	1	1	149	42.9	19.3	0.7279	76	31.7	726							
OAK065	m	11	Bang	0	0	0	1	1	0	0	1	143	47.5	23.2	2.1414	82	40.6	721	10987	30810	6094	15057	10817		
OAK066	f	11	Bang	0	0	0	1	1	0	0	1	148	58.0	26.5	2.4883	85	41.1	538	6745	10215	12183	2500	17589		2819
OAK067	f	11	Bang	0	0	0	1	1	0	0	1	161	60.5	23.3	1.8695	84	37.1	555							
OAK068	m	11	Bang								1														
OAK069	m	11	Wh. UK	0	0	0	1	1	0	0	1	160	61.0	23.8	2.2632	90	39.7	615	27349		15249	11652	17424	3930	6837
OAK070	m	11	Bang	0	0	0	1	1	0	0	1	145	30.4	14.5	-1.5658	64	20.2	859	16343	8983	17642	15581	15712	7979	7283
OAK071	f	11	Bang	0	0	0	1	1	0	0	1	147	37.5	17.4	-0.0607	76	30.5	840	12909	13152	9818	15854	11578	8681	6944
OAK072	m	11	Bang	0	0	0	1	0	0	0	1	152	40.3	17.4	0.2948	73	22.1	640	8630	6930	9668	9526	11013		
OAK073	m	11	Bang	0	0	0	1	1	0	0	1	142	38.6	19.1	1.0041	75	39.1	910				14913	13087		5600
OAK074	m	11	Bang	1	1	1	1	1	2	1	1	142	31.1	15.4	-0.8516	67	24.8	862	11276	10679	14176	16172	14037	21227	14691
OAK075	m	11	Bang	1	1	1	1	1	1	1	1	144	44.0	21.2	1.6597	75	36.0	714	9854	9000	6099	8595	9876	2561	3519
OAK076	m	11	Bang	0	1	1	1	0	0	1	1	142	29.9	14.8	-1.2766	61	14.7	733							
OAK077	m	12	SA Oth	0	0	0	1	1	1	0	1	151	40.0	17.5	0.0772	62	24.2	681		24941			21378	2921	6229
OAK078	m	12	Bang	0	0	0	1	0	1	0	1	153	39.1	16.7	-0.3597	66	19.4	641	3384	6016	7377	8954	6112		
OAK079	m	11	Bang	1	1	1	1	0	2	1	1	167.5	53.8	19.2	1.0160	79	29.7	631		10718	8313	9801	9252		
OAK080	f	12	Bang	0	0	0	1	1	0	0	1	144.5	30.3	14.5	-1.9957	61	19.4	840	13031	6083	11085	7610	8704	1878	2133
OAK081	m	11	Bang	0	0	0	1	1	2	0	1	142	41.7	20.7	1.5074	70	33.5	689	10062	10138	17242	16264	14333	9225	

OAK082	f	11	Turk	0	0	0	1	1	1	0	1	140.5	33.1	16.8	-0.3372	62.5	23.1	732		4546	6565	12295	5302	5697	
OAK083	f	11	Bang	0	0	0	1	1	1	0	1	159	65.6	25.9	2.3958	89	44.2	642							
OAK084	m	13	Wh. UK								1														
OAK085	f	11	Bang	0	0	0	1	1	1	0	1	140	27.3	14.0	-1.9924	60	22.6	923		4786	4352	4769	5350		
OAK086	m	11	Bang	1	1	0	1	1	0	1	1	141	39.1	19.8	1.2352	70	33.4	742	9989	8008	12909	14507	16269	18011	
OAK087	f	11	Bang	0	1	1	1	1	2	0	1	148	51.4	23.5	1.8980	85	38.2	629							
OAK088	m	11	Bang	0	1	0	1	0	1	1	1	148	62.6	28.6	2.9842	94	45.5	576	10345	9403	9540		9945		
OAK089	m	11	Bang	0	0	0	1	1	1	1	1	141	32.0	16.1	-0.4243	61	18.2	691	14833		17652	16573	17525	7098	4971
OAK090	f	11	Oth.	0	1	1	1	1	1	1	1	154	39.7	16.7	-0.3510	61	19.8	644		7137	5998	2267			
OAK091	m	11	Bang	0	0	0	1	0	0	0	1	149.5	42.2	18.9	0.9066	71	25.6	609	4818		9446				
OAK092	f	11	Bang	1	1	1	1	1	1	1	1	153	56.1	24.0	2.0077	83	41.5	687		6003	5665	6284		7261	
OAK093	m	11	Bang	1	1	1	1	1	1	1	1	140.5	35.8	18.1	0.6066	58	29.3	760	4031	4653	4073		5856		
OAK094	m	12	Bang	0	0	0	1	0	1	0	1	161.5	59.1	22.7	1.8249	88	38.6	655							
OAK095	f	11	Bang	1	1	0	1	0	1	0	1	159	79.5	31.4	3.1818	102	51.2	613							
OAK096	f	11	Bang	0	0	0	1	1	0	0	1	152.5	57.7	24.8	2.1820	87	42.1	656	10254	6617	13260	13141	8726	3443	9648
OAK097	f	11	Wh. UK	1	1	1	1	0	0	1	1	147	55.6	25.7	2.3565	87	38.3	497	8548	5826	8507	8819	8509		
OAK098	f	11	Bang	0	0	0	1	1	0	0	1	134.5	37.1	20.5	1.1187	70	37.0	779	8257	9831	10069	8438	6403	8804	2354
OAK099	f	11	Bang	0	2	0	1	1	0	0	1	153	36.7	15.7	-0.9158	66	22.6	802	8799	7825	6943	8660	7988		4882
OAK100	f	11	Bang	0	2	0	1	1	0	0	1	141	31.4	15.8	-0.8497	64	25.7	851	10770	12476	8679	7958	10412	7261	3333
OAK101	f	12	Wh. UK								1														
OAK102	f	11	Wh. UK	0	0	1	1	0	2	1	1	149	41.7	18.8	0.5305	72	29.7	717	9304	8358	8083	7876	7819		
OAK103	f	11	Bang	0	0	0	1	0	0	0	1	133	26.6	15.0	-1.3013	62	18.5	775					8726	3443	9648
OAK104	f	11	Bang	0	0	1	1	1	0	1	1	149	31.3	14.1	-1.9409	62	19.5	880	17913	21417	10204	12102	11509	6236	19760
OAK105	m	12	Wh. UK	0	0	0	1	1	0	0	1	157	50.6	20.5	1.2434	73	35.9	740	8724	2216	9624	10466	6007	1753	10460
OAK106	f	11	Wh. UK	1	0	1	1	1	2	1	1	154	44.4	18.7	0.5072	72	29.1	697	4426	6145			4883		
OAK107	m	11	Wh. UK	0	0	0	1	1	1	0	1	151	61.7	27.1	2.7924	95	44.3	605	12223	8207	13191	13994	11044	28073	5652
OAK108	f	11	Wh. UK	0	0	0	1	0	0	1	1	156	50.6	20.8	1.2047	69	30.6	567							
OAK109	m	11	Wh. UK	0	0	0	1	1	2	1	1	150	47.3	21.0	1.6053	78	35.1	695	8376	8968	8114	9242	9186		
OAK110	f	11	Bang	1	1	1	1	0	1	1	1	150	43.1	19.2	0.6680	63	30.8	715	9784	3663	6923	13565	10760	1277	4955
OAK111	f	11	Bang	0	0	0	1	1	0	0	1	155	54.1	22.5	1.6740	89	42.2	796	4521	14337	8404	8452	7351	6707	3348
OAK112	f	11	Wh. UK								1														
OAK113	m	11	Bang	0	0	0	1	0	1	0	1	154	38.7	16.3	-0.2939	59	20.5	698	16808	7530	13636	15136	10442	13582	18925
OAK114	m	11	Bang	0	0	0	1	1	0	0	1	169	65.8	23.0	2.1009	89	37.8	565			8184	7047	5697		
OAK115	m	11	Bang	0	0	0	1	1	0	0	1	135	29.0	15.9	-0.5359	61	28.0	872	1569	17454	9602	10444	9218	8561	6104
OAK116	m	11	SA Oth	0	0	0	1	0	1	0	1	138	25.2	13.3	-2.5960	57	13.2	831	22654	24978					
OAK117	f	11	Bang	0	0	0	1	0	0	0	1	148	30.0	13.7	-2.2462	58	16.9	868	1999	7931	4972	14261	16543	17198	12878
OAK118	m	11	SA Oth	1	1	1	1	1	1	0	1	157	67.3	27.3	2.8251	76	44.3	568							
OAK119	m	11	Wh. UK	0	1	0	1	1	1	0	1	138	37.6	19.9	1.2617	74	37.2	819	6081	6768	9129	8096	6843		

OAK120	m	11	Bang	0	0	0	1	1	0	0	1	143	40.4	19.8	1.2183	79	36.8	824	5436	4700		10433	8291	5590	
OAK121	f	12	SA Oth	0	0	0	1	1	1	0	1	144	53.9	26.0	2.2243	88	23.9	48							
OAK122	f	11	Bang	1	1	0	1	1	1	0	1	150	44.4	19.7	0.8693	83	35.2	786		9893	12456	8492	10018	8148	
SPW001	m	12	Bang	1	0	0	1	1	1	0	1	164	59.0	21.9	1.6452	88	38.3	692	10509	9453	14380	10417	9252	14507	16269
SPW002	m	11	Bang	0	0	0	1	1	0	0	1	152.5	45.8	19.7	1.1972	81	33.3	737	10119	11173	9479	8126	9447	16573	17525
SPW003	m	11	Bang	1	1	1	1	1	1	0	1	152.5	48.1	20.7	1.5080	82	35.0	710	10175	10363	5613	7639	4425	10298	
SPW004	f	11	Bang	1	0	0	1	1	1	0	1	137	31.6	16.8	-0.3038	64	23.1	728			11701	11877	10324	14022	12011
SPW005	f	12	Bang	1	1	0	1	1	1	0	1	136.5	34.6	18.6	0.1799	71	31.4	774	17220	9572	9465	12286	18797	2267	
SPW006	m	11	Wh. UK	1	1	0	1	1	2	0	1	149	38.9	17.5	0.3321	79	23.5	671		15274	13785	8287	8077	14247	2166
SPW007	m	12	Blk Afr	0	0	0	1	0	1	0	1	156	58.7	24.1	2.1430	84	40.9	650		9302	6918		9603	6284	
SPW008	m	12	Bang	1	1	0	1	1	1	0	1	143.5	38.0	18.5	0.4891	81	31.1	778	3886	4500	9217	10407	10150		5856
SPW009	m	12	Bang	0	0	0	1	1	1	0	1	145	45.1	21.5	1.5149	83	36.4	709	15465	13577	11058	12015	17711		
SPW010	m	12	Bang	1	0	0	1	1	1	1	1	152	47.7	20.6	1.2799	74	29.2	556		1657	10996	14437	11389	13141	8726
SPW011	m	12	Bang	0	0	0	1	1	1	0	1	152.5	43.7	18.8	0.6277	69	24.0	568	11497	10187		13964	10217	8819	8509
SPW012	f	13	Bang	1	1	1	1	1	1	0	1	153	40.0	17.1	-0.7810	63	22.9	687	13147	9229	19787	10446	18877	8438	6403
SPW013	f	11	Bang	0	0	0	1	1	0	0	1	157	53.5	21.7	1.4636	86	36.0	657	8605	8558	11038	9487	9331		7988
SPW014	f	12	Wh. UK	1	1	0	1	1	0	1	1	147	52.5	24.3	1.8816	79	38.8	598		4532	6413	7543	5246	7532	
SPW015	f	12	Bang	0	0	0	1	1	0	1	1	145.5	38.0	17.9	-0.0803	70	26.4	709	7436	6856	5064	5886	6578	7958	10412
SPW016	m	12	Wh. UK	1	1	0	1	0	1	1	1	161.5	55.5	21.3	1.4669	86	36.3	683							
SPW017	m	13	Blk Afr	1	1	0	1	0	1	0	1	163	47.5	17.9	-0.0518	73	21.8	547	13263	10691	7884	8050	6495	12102	11509
SPW018	m	12	Bang	0	0	0	1	1	0	1	1	156	59.5	24.4	2.2074	85	39.6	585							
SPW019	m	12	Wh. UK	1	1	0	1	0	0	0	1	164.5	52.5	19.4	0.8616	73	31.6	682							
SPW020	m	12	Bang	0	0	0	1	1	0	0	1	157.5	40.0	16.1	-0.6978	74	20.7	713	8527		10587	14549	7819	13994	11044
SPW021	m	12	Bang	0	0	0	1	0	1	0	1	163.5	56.5	21.1	1.4259	86	34.9	643		19965	8268	10578	13683	9242	4883
SPW022	f	12	Bang	1	1	1	1	1	1	0	1	153.5	54.5	23.1	1.6128	80	40.3	701							
SPW023	f	12	Bang	0	0	0	1	0	0	0	1	157	46.5	18.9	0.2968	86	29.8	698	8732	6999	13720	16999		13565	10760
SPW024	m	12	Wh. UK	0	0	0	1	1	1	1	1	156	38.0	15.6	-1.0257	66	19.2	731	3119	20298	17797	13696		9587	
SPW025	m	13	Bang	1	1	1	1	1	1	0	1	171.5	66.5	22.6	1.6141	87	37.2	566	12999	14623	14481	14606	12427	8452	
SPW026	f	11	Wh. UK	1	1	1	1	1	1	0	1	165.5	68.0	24.8	2.1851	80	41.5	586	8112	7967	13407	14651	10517	15136	10442
SPW027	m	11	Wh. UK	1	0	0	1	1	1	1	1	153	56.0	23.9	2.2816	73	40.7	666	5878	6719	8221	5354	7072	7047	
SPW028	m	12	Bang	0	0	0	1	0	0	0	1	162.5	77.0	29.2	2.9166	92	48.1	591		12112		8767	11070	10444	9218
STP001	m	12	Bang	0	0	0	1	0	1	0	0	163.5	67.6	25.3	2.3610	86	40.4	521	17535	13603					10257
STP002	m	12	Bang	0	0	0	1	0	0	0	0	153	37.5	16.0	-0.7632	70	18.8	690	9767		7753		10261	11670	12975
STP003	m	12	Bang	0	0	0	1	1	0	0	0	145.5	38.6	18.2	0.3947	76	29.6	758	5547	6753			10541	7347	7830
STP004	m	11	Bang	1	1	1	1	1	1	1	0	133	25.2	14.2	-1.7422	64	18.8	835	17596	5966	5021	19236	20346	12496	12945
STP005	m	12	Bang	0	0	0	1	1	0	0	0	144	30.9	14.9	-1.5374	62	16.2	751	8444	9074			7949	5125	12075
STP006	m	11	Bang	0	0	0	1	1	0	0	0	153	46.6	19.9	1.2680	77	30.6	647							
STP007	m	11	Blk Car	0	0	0	1	1	0	0	0	145.5	37.0	17.5	0.3111	68	28.9	797							

STP008	m	12	Blk Car	0	0	0	1	0	1	0	0	149	38.8	17.5	0.0448	71	24.0	687	15046	1874	10185	11266	16102	9996	11760
STP009	m	12	Bang	0	0	0	1	0	1	0	0	134.5	26.9	14.9	-1.5618	64	20.9	825							
STP010	m	12	Bang	0	0	0	1	0	1	0	0	149.5	38.4	17.2	-0.1038	68	22.0	665	10254	6617	13260	13141		8726	3443
STP011	m	12	SA Oth	0	0	0	1	1	0	0	0	138.5	27.3	14.2	-2.0845	61	18.3	838	19998	22453	10507	16426	5163	5353	
STP012	m	12	Oth	0	0	0	1	1	0	0	0	156.5	74.2	30.3	3.0430	101	50.0	630	19932		2433	13811	2613	22250	26019
STP013	m	12	SA Oth	0	0	0	1	1	0	0	0	153	51.2	21.9	1.6284	82	37.7	707					2828	13889	
STP014	m	12	Bang	0	0	0	1	0	1	0	0	144	40.6	19.6	0.9261	71	33.0	745	16026	11058	17676	12299	11643	12064	11090
STP015	m	12	Bang	0	0	0	1	1	0	0	0	148.5	55.2	25.0	2.3155	84	43.4	696		17455	15899	11944	19585		
STP016	m	12	Bang	0	0	0	1	0	0	0	0	150	38.8	17.2	-0.0713	72	21.5	647		8633	17410	11268	9550	12173	6099
STP017	m	13	Bang	0	0	0	1	1	0	0	0	151	50.3	22.1	1.4697	81	38.6	722							
STP018	m	11	Bang	0	0	0	1	1	0	0	0	143	29.3	14.3	-1.6732	62	13.1	747	18909		22766	18413	19064	17765	16641
STP019	m	12	Bang	0	0	0	1	1	0	0	0	140.5	37.7	19.1	0.7481	66	23.2	564			12890	14579		24702	
STP020	m	12	Bang	0	0	0	1	1	0	0	0	151.5	56.3	24.5	2.2226	89	41.5	658							
STP021	m	11	Bang	0	0	0	1	1	0	0	0	142.5	33.8	16.6	-0.1110	67	25.4	785	9993		16749	17056	18460		13473
STP022	m	12	Bang	0	0	0	1	0	0	0	0	149.5	44.9	20.1	1.1018	69	28.7	593							
STP023	m	12	Bang	1	1	1	1	1	1	0	0	160	62.7	24.5	2.2156	74	42.3	660	6472	10235	14835		12533	13117	21011
STP024	m	12	Bang	1	1	0	1	0	1	0	0	143	34.8	17.0	-0.1888	69	28.6	822	12382			8014	1618		
STP025	m	11	Bang	1	1	0	1	1	1	0	0	146	35.9	16.8	-0.0059	67	26.5	793		15046	11266	10185		16102	9996
STP026	m	12	Bang	1	1	1	1	1	1	1	0	153.5	39.0	16.6	-0.4448	63	21.9	709		16650	13498	11095	2312	7801	8196
STP027	m	12	Bang	1	1	0	1	1	0	0	0	145.5	48.0	22.7	1.8282	73	42.2	793							
STP028	m	12	Bang	0	1	0	1	1	1	0	0	149.5	34.3	15.3	-1.2103	63	21.7	814	24568	11393	6083	7841	10125	9400	9117
STP029	m	11	Bang	0	1	0	1	1	0	1	0	144.5	37.6	18.0	0.5515	70	29.3	768		17272	16385	17597	2499	9762	
STP030	m	12	Bang	0	0	0	1	1	0	0	0	148.5	39.0	17.7	0.1455	60	25.0	694		13047		20985	16035	12577	
STP031	m	12	Bang	0	0	0	1	1	0	0	0	154	44.4	18.7	0.5998	73	28.5	683	9413	10243	8222	12056	17735		
STP032	m	12	Bang	0	0	0	1	1	0	0	0	154.5	72.6	30.4	3.0555	97	50.9	668							
STP033	m	12	Bang	1	1	1	1	1	1	1	0														
STP034	m	12	Bang	0	0	0	1	1	0	0	0	163.5	46.0	17.2	-0.0901	71	23.2	650							
STP035	m	12	Bang	1	1	2	1	1	1	1	0	147	29.1	13.5	-2.8047	60	15.9	871	12756	12534	12634	13562		5864	9013
STP036	m	12	SA Oth	0	1	0	1	1	0	1	0	160.5	73.5	28.5	2.8407	98	45.9	541							
STP037	m	12	SA Oth	0	0	0	1	1	0	0	0	145	43.6	20.7	1.3079	71	36.5	757							
STP038	m	12	Bang	1	1	1	1	1	1	1	0	151.5	38.4	16.7	-0.3444	68	22.5	710	6583	10168	10087	10770		9059	11460
STP039	m	12	Bang	0	0	0	1	1	0	0	0	160.5	69.6	27.0	2.6368	94	44.3	570	12004	13537	4005	11392	10504	11169	7806
STP040	m	12	Bang	1	1	2	1	1	1	0	0	161	52.9	20.4	1.2055	78	36.0	742	11557	9999	4633	1672		9690	7608
STP041	m	12	Bang	0	1	0	1	1	0	1	0	147.5	47.5	21.8	1.6181	83	37.5	713							
STP042	m	12	Bang	0	0	0	1	1	0	0	0	136.5	33.2	17.8	0.2081	62	21.1	622	9993	12302	16749	17056	18460	11591	13473
STP043	m	11	Bang	0	0	0	1	0	0	0	0	150	37.2	16.5	-0.1724	61	22.9	738	26027	29086	27007	24687	25230	22230	23245
STP044	m	11	Bang	0	0	0	1	0	0	0	0	145	44.2	21.0	1.6054	72	33.8	670	14834	11324	10432	9584	14332		
STP045	m	12	Bang	0	0	0	1	1	0	0	0	147	37.7	17.4	0.0299	69	25.9	734	11204	8486			12138		

STP046	m	12	Bang	0	0	0	1	0	1	0	0	146	35.7	16.7	-0.3347	67	22.9	727							
STP047	m	12	Bang	0	0	0	1	0	1	0	0	159	72.5	28.7	2.8587	91	47.8	619	9642	4837	5476		7610	7528	12585
STP048	m	12	SA Oth	0	0	0	1	1	0	0	0	154	55.4	23.4	1.9843	83	39.3	655	10003	12338	8536	6046	10438	10633	9721
STP049	m	12	SA Oth	0	1	0	1	1	1	0	0	152.5	34.5	14.8	-1.5890	67	23.5	893							
STP050	m	11	Bang	0	0	0	1	1	0	0	0	150.5	45.9	20.3	1.3820	78	35.4	754		8916				13681	11696
STP051	m	12	Bang	0	0	0	1	1	0	0	0	155	43.0	17.9	0.2448	72	24.0	637	9621	5655	12890	14579	24702		11825
STP052	m	12	SA Oth	0	0	0	1	0	1	0	0	143	33.5	16.4	-0.5432	62	24.4	785	21832	13782	5463	21821	16214	14578	18100
STP053	m	12	Bang	0	0	0	1	0	1	0	0	145	33.0	15.7	-0.9717	57	13.9	639	10539	7932			7043	10655	20786
STP054	m	12	Bang	1	1	2	1	1	1	0	0	189	41.6	11.6	-5.0760	63	6.3	843	11249				6275	1031	12211
STP055	m	12	Bang	0	0	0	1	1	0	0	0	159	60.1	23.8	2.0722	87	41.0	669							
STP056	m	12	Bang	1	1	2	1	1	1	1	0	163	60.0	22.6	1.8066	79	39.5	687							
STP057	m	12	SA Oth	1	1	0	1	1	1	1	0	151	32.3	14.2	-2.1422	56		445	18210	16606	14064	15891	16572	20085	17007
STP058	m	12	Bang	0	0	0	1	1	1	0	0	143.5	54.2	26.3	2.5317	91	47.1	751				12950	10683	2149	14654
STP059	m	12	Bang	1	1	0	1	1	1	0	0	168	69.3	24.6	2.2273	82	39.9	532							
STP060	m	12	Bang	1	1	0	1	1	1	0	0	147	35.8	16.6	-0.4361	70	24.2	766							
STP061	m	12	Wh. UK	1	1	1	1	1	1	1	0	153	47.5	20.3	1.1681	80	35.4	749							
STP062	m	11	Bang	0	1	0	1	1	1	0	0	151	36.4	16.0	-0.5039	65		20	12410	7991					
STP063	m	12	Bang	0	0	0	1	1	0	0	0	151.5	36.5	15.9	-0.8371	58	18.0	687			11114	11945	10456	6328	21775
STP064	m	12	Bang								0	143	40.5	19.8	1.0056	68	34.2	760		7449	14500	9345	13372	10368	3914
STP065	m	11	Bang								0	148	51.5	23.5	2.2000	82	39.6	669							
STP066	m	11	Bang								0														
STP067	m	12	Bang	0	0	0	1	0	1	1	0	157	54.3	22.0	1.6693	82	38.0	694	17510	9584					17170
STP068	m	11	Bang	0	0	0	1	0	0	0	0	150	52.8	23.5	2.1908	87	39.8	671	10479				10703	15702	10810
STP069	m	12	Bang	0	0	0	1	0	1	0	0	164	65.8	24.5	2.2103	95	42.6	660					7698	8168	7790
STP070	m	12	SA Oth	0	0	0	1	0	1	0	0	153	60.2	25.7	2.4342	91	42.9	629							
STP071	m	12	SA Oth	0	0	0	1	0	0	1	1	151	33.0	14.5	-1.8793	61		280							
STP072	m	11	Bang	0	0	0	1	0	1	1	1	141	46.8	23.5	2.2058	81	39.7	680							
STP073	m	11	Bang	0	0	0	1	0	1	0	1	148.5	53.9	24.4	2.3792	82	43.5	731							
STP074	m	12	Bang	0	0	0	1	0	1	0	1	153	56.5	24.1	2.1461	85	41.2	666							
STP075	m	12	Bang	1	1	1	1	1	1	1	1	136.5	47.3	25.4	2.3781	69	38.6	560							
STP076	m	12	Bang	1	1	1	1	1	1	1	1	158.5	50.7	20.2	1.1322	70	30.6	606							
STP077	m	11	Bang	0	0	0	1	0	1	0	1	151	44.9	19.7	1.1967	78	34.2	762							
STP078	m	12	Bang	0	0	0	1	0	0	0	1	158	69.8	28.0	2.7673	96	45.1	555							
STP079	m	12	Bang	1	1	1	1	1	1	1	1	155	39.4	16.4	-0.5330	68	20.3	683		10314	6092	15717		15936	7654
STP080	m	12	Bang	0	0	0	1	0	0	0	1	152	40.6	17.6	0.0916	65	21.8	622		10003	12338	8536	6046	10438	
STP081	m	12	Bang	0	0	0	1	0	1	0	1	146.5	36.6	17.1	-0.1702	70	22.8	700			12236	11157	11731	6328	
STP082	m	12	Bang	0	0	0	1	0	1	0	1	155.5	45.4	18.8	0.6217	74	31.9	764							
STP083	m	12	Bang	1	1	1	1	1	2	1	1	136.5	33.8	18.1	0.3541	65	34.5	859	17596	5966		19236	20346	12496	

STP084	m	11	Bang	1	1	1	1	1	2	1	1	132.5	31.2	17.8	0.4470	66	24.6	693	10546	10656	15743	15936	10054		
STP085	m	11	Bang	0	0	0	1	0	0	0	1	144	31.8	15.3	-0.9114	63	22.9	836	21633	17454	18354	17373			
STP086	m	12	Bang	1	1	1	1	1	1	1	1	146.5	33.7	15.7	-0.9675	63	25.6	862			15022	14946	15844	15503	13901
STP087	m	12	Bang	0	0	0	1	0	0	0	1	155.5	61.1	25.3	2.3576	91	45.0	723							
STP088	m	12	SA Oth	0	0	0	1	0	1	0	1	164	53.7	20.0	1.0604	70	35.7	759					6172	7546	7460
STP089	m	12	Bang	1	1	0	1	0	1	0	1	150.5	47.2	20.8	1.3385	79	35.8	726							
STP090	m	12	Bang	0	0	0	1	0	1	1	1	140	32.9	16.8	-0.3139	61	29.1	844		10322	14655		12764	13113	21044
STP091	m	11	Bang	0	0	0	1	0	1	0	1	143.5	33.7	16.4	-0.2668	65	22.1	743			12954	12167	13119	8534	11002
STP092	m	12	SA Oth	0	0	0	1	0	0	0	1	147.5	32.7	15.0	-1.4401	61	23.2	869	13011	14566	14453	15011	12453		
STP093	m	12	Wh. UK	1	1	2	1	1	1	0	1	137.5	29.1	15.4	-1.1786	58	23.8	841	11165	9770				11218	7246
STP094	m	12	Bang	0	0	0	1	0	1	0	1	146	40.5	19.0	0.7102	76	34.4	816		17322	9435	10433	11354	18333	
STP095	m	12	Bang	0	0	0	1	1	1	0	1	165	53.4	19.6	0.9386	81	32.7	695							
STP096	m	12	Bang	1	1	1	1	1	1	1	1	148	60.9	27.8	2.7464	91	43.8	555				10051	9177	8382	
STP097	m	12	Wh. UK								1	158.5	55.3	22.0	1.6649	82	35.9	626							
STP098	m	12	Wh. UK								1														
STP099	m	12	Bang	0	1	1	1	1	1	1	1	151.5	43.0	18.7	0.6051	68	21.0	501							
STP100	m	12	Wh. UK	1	1	2	1	1	1	0	1	150	49.0	21.8	1.6036	77	35.2	648							
STP101	m	12	Bang	0	1	1	1	1	2	1	1	160	62.7	24.5	2.2156	88	40.8	608							
STP102	m	12	Wh. UK	0	0	0	1	1	0	0	1	138.5	34.3	17.9	0.2370	67	20.9	610		12973					
STP103	m	12	Bang	1	1	1	1	1	2	1	1	145.5	48.0	22.7	1.8282	81	37.4	660							
STP104	m	12	Wh. UK	0	0	0	1	1	0	0	1	148	50.5	23.1	1.9167	84	40.2	714							
STP105	m	12	Bang	0	1	0	1	1	1	1	1	158	54.2	21.7	1.5859	84	39.3	755							
STP106	m	12	Wh. UK	0	0	0	1	1	0	0	1	146	46.2	21.7	1.5758	78	35.0	658							
STP107	m	12	Bang	1	1	0	1	1	2	1	1	158	63.2	25.3	2.3660	90	41.2	576							
STP108	m	12	Wh. UK	1	1	1	1	1	1	0	1														
STP109	m	11	Bang	0	0	0	1	1	0	0	1	141.5	37.9	18.9	0.9246	73	37.1	877	8605	8558	11038	9487		9331	12580
STP110	m	12	Wh. UK	1	1	2	1	1	1	0	1	145	50.3	23.9	2.1034	78	38.2	609							
STP111	m	12	Bang	0	0	0	1	1	0	0	1	149.5	39.8	17.8	0.2029	66	25.5	694	5716		2655		10937	11314	8696
STP112	m	12	Bang	1	1	2	1	1	1	0	1	146	42.4	19.9	1.0351	77	32.7	716	19240						
STP113	m	12	Bang	1	1	2	1	1	1	0	1	154	39.0	16.4	-0.5067	73	20.6	689	19357	18374	11192	10769	4659	11136	12035
STP114	m	11	Bang	0	0	0	1	1	0	0	1	138	29.6	15.5	-0.7718	64	22.8	814							
STP115	m	12	Bang	1	1	1	1	1	1	0	1	162	64.7	24.7	2.2461	83	37.9	481							
STP116	m	12	Bang	1	1	0	1	0	2	1	1	146	47.5	22.3	1.7336	77	36.7	666	4020	6416			8425		
STP117	m	12	SA Oth	1	1	2	1	1	1	0	1	155	53.5	22.3	1.7298	73	39.5	730							
STP118	m	12	Bang	1	1	2	1	1	1	0	1	139.5	30.0	15.4	-1.1616	62	20.0	777	6644	6787	5523		5845	8256	3537
STP119	m	12	Bang	1	1	0	1	1	1	1	1	136	32.9	17.8	0.1937	69	30.4	801	27349		15249	11652	17424		6837
STP120	m	12	Bang	0	0	0	1	1	0	0	1	138.5	36.4	19.0	0.7009	71	31.7	756	11497	10187		13964	10217	8819	
STP121	m	12	Bang	1	1	2	1	1	1	0	1	145.5	32.8	15.5	-1.1081	63	22.3	814	9543	16654	14324			11321	7642

STP122	m	11	Bang	0	1	0	1	1	0	1	1	189	78.5	22.0	1.8558	101	41.3	701							
STP123	m	12	Bang	1	1	0	1	1	1	1	1	149	59.0	26.6	2.5710	94	42.8	587	13989	3404	12219	1342	6956	7676	6747
STP124	m	12	Bang	1	1	2	1	1	1	0	1	136	30.9	16.7	-0.3578	64	22.3	723		6343	6475	6382			
STP125	m	11	Bang	1	1	2	1	1	1	1	1	146.5	48.8	22.7	2.0348	81	36.1	618							
STP126	m	11	Bang	0	0	0	1	1	0	0	1	158	42.2	16.9	0.0268	69	21.6	658	17434	15334	16329		17434	14332	18743
STP127	m	12	Bang	1	1	0	1	1	1	0	1	156	57.6	23.7	2.0505	82	40.6	669	7829	21871		1512	8948	15446	4603
STP128	m	12	Bang	1	1	0	1	0	0	1	1	142	37.6	18.6	0.5695	71	32.5	795	12687	12273	3396	16078	10429	10076	11050
STP129	m	12	Bang	0	1	0	1	1	0	1	1	152	68.9	29.8	2.9919	101	46.0	510							
STP130	m	12	Bang	0	1	0	1	1	1	1	1	146	46.8	22.0	1.6502	78	37.4	705	14200	11464	12500	1517	8300	8698	11357
STP131	m	11	Bang	0	0	0	1	1	0	0	1	145	44.2	21.0	1.6054	75	34.1	677							
STP132	m	12	Bang								1	153	35.2	15.0	-1.4351	65	19.8	801							
STP133	m	12	Bang								1	151	50.2	22.0	1.6660	79	34.9	618							
STP134	m	12	Bang	0	1	1	1	0	1	1	1	141.5	32.6	16.3	-0.6026	66	20.1	712	17343	16343	14653	10331			
STP135	m	11	Bang	1	1	0	1	1	1	1	1	150	55.4	24.6	2.4117	90	41.5	655							
STP136	m	12	Bang								1	140.5	28.9	14.6	-1.7427	62	7.8	634		16888	15333	10442	18956		
STP137	m	12	Bang	0	1	0	1	1	1	1	1	151	57.6	25.3	2.3565	85	42.3	640	7424		17306	7580	20387	16124	15672
STP138	m	12	Bang	0	1	0	1	1	2	1	1	165	48.6	17.9	0.2232	70	22.8	568	18133	7293	14468	6088	12403	14192	6455
STP139	m	12	Bang	0	1	0	1	1	1	1	1	162	47.1	17.9	0.2672	70	34.2	881							
STP140	m	12	Bang	1	1	1	1	1	1	1		147.5	47.0												

Appendix 14 – Publications and Conferences

a) MCNAMARA, E., HUDSON, Z. & TAYLOR, S. J. C. 2010. Measuring activity levels of young people: the validity of pedometers. *Br Med Bull,* 95**,** 121-37.

b) MCNAMARA, E., HUDSON, Z. & TAYLOR, S. J. 2011. Pedometer determined physical activity levels amongst 11-12yr olds in an inner city region of London, UK. *World Confederation for Physical Therapy Congress.* Amsterdam.

c) MCNAMARA, E., HUDSON, Z. & TAYLOR, S. J. 2011. The validity of pedometers as a measure of physical activity in adolescents: a review of the literature. *Physical Activity Research Group Symposium.* University College London.

d) HUDSON, Z., TAYLOR, S. J. C. & MCNAMARA, E. 2012. Physical activity in adolescents in an Olympic borough prior to the London 2012 Olympic Games. *59th Annual Meeting of the American College of Sports Medicine.* 29 May -2 June, San Francisco, USA.

a)

Published Online June 18, 2010

Measuring activity levels of young people: the validity of pedometers

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The valid measurement of physical activity has the potential to be a very useful tool in countering the obesity epidemic. Previously, reviews have been carried out to investigate the validity of pedometers among adults. This paper aimed to carry out a similar review among children. A literature search was performed in PubMed, Web of Science, PsycINFO, CINAHL and SportDISCUS. Here, 25 papers investigating the validity, reliability and feasibility of pedometers for children were included in the study. Pedometers correlated highly in terms of both criterion (direct observation) and convergent validity (heart-rate monitor, accelerometer). Intra- and inter-unit reliability was also consistently high. Few studies report on feasibility issues of pedometer use in children, particularly compliance, reactivity and dealing with missing data. Given that they are both cheap and easy to use, pedometers can be effectively utilized as a valid determinant of physical activity levels among children and adolescents, particularly in large-scale epidemiological studies. There remains a need for accepted outliers and proper protocol regarding missing data.

Keywords: pedometer/physical activity/validity/reliability/feasibility/children/adolescents

Accepted: May 19, 2010

Introduction

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It is widely recognized that the prevalence of childhood obesity is increasing worldwide. This is supported by the results of a number of studies that highlight increased overweight and obesity in the UK[1] and other countries such as the USA,[2,3] Spain[4] and Denmark.[5] According to the Centre for Disease Control & Prevention, worldwide obesity rates have doubled among children and tripled among adolescents since 1980.[6,7]

Opposite trends have been found regarding physical activity among children and adolescents. The rate of physical activity in children/

British Medical Bulletin 2010; 95: 121–137
DOI: 10.1093/bmb/ldq016

adolescents is declining,[8,9] and the rate of energy expenditure among children is 25% lower recommended.[8] In the UK, only 33 and 21% of boys and girls, respectively, are reaching current government physical activity guidelines.[1] There is also evidence that current activity guidelines underestimate the amount of activity needed to maintain a healthy lifestyle.[10]

On the basis of the above trends and a basic interpretation of the energy balance equation,[11] there is a strong case to suggest that obesity is associated with inactivity. A recent systematic review by Reichert *et al.*[12] found that physical activity had a protective effect on adiposity in children.

The effective measurement of physical activity among children and adolescents, for both intervention and observational studies, and in monitoring and promoting physical activity with a view to countering the obesity epidemic, is of great importance. One of the more commonly used and readily available methods of physical activity assessment is the pedometer. Pedometers are cheap, easy to use devices that give a reading of steps. Typically, they measure steps by using a spring-suspended mechanical lever that moves up and down in response to vertical displacement. Each of these movements is recorded and usually displayed digitally. Pedometers can also provide a number of derived output readings. These vary depending on the brand, and include distance travelled, calories expended and time spent at specific activity intensities.[13] These additional features are estimates and have not been validated among children.

Given their low cost, pedometers are practical for use in large-scale epidemiological studies. They have the potential to be a very useful method of measuring activity and provide valuable information to potentially counter obesity. However, as with all evaluation tools, their effective use is dependent on pedometers being validated as an accurate and reliable determinant of physical activity levels. Previous studies have been conducted reviewing the validity of pedometers. However, these have differed in that they have investigated a number of different methods of physical activity measurement[14] or looked at the validity of pedometers among adults.[15] This study aims to review all published papers investigating the validity, reliability and feasibility of pedometers as determinants of physical activity among children and adolescents.

Methods

Search strategy

The electronic databases PubMed, Web of Science, PsycINFO, CINAHL and SportDiscus were used to search for articles that satisfied the inclusion criteria. The search was limited to articles from 1990 to the present date, given that the technology used in pedometers is constantly evolving and the current technology only began being reported in the mid-1990s. The specific search strategy consisted of three unique searches of similar terms, separated by the Boolean term OR: 'pedometer OR pedometers OR pedometry'; 'validity OR accuracy OR reliability OR feasibility OR reactivity'; 'children OR adolescents'. These three separate searches were then combined using the Boolean term AND to gather all possible papers and prevent duplication. Results were compared across all five search engines and again, any duplicates removed. The titles and abstracts from all identified papers were assessed to determine their appropriateness for the research question. Full manuscripts of the articles deemed relevant and adhering to the inclusion and exclusion criteria were ordered. The reference lists of these papers were then cross-checked to identify any possible additional publications not previously found.

Inclusion and exclusion criteria

The inclusion criteria were:

- studies reporting the validity, reliability, consistency or accuracy of pedometers and step count monitors;
- full text, English language publications;
- studies of males or females of any ethnicity between the age of 4–20 years.

The exclusion criteria were:

- case reports, editorials, comments, letters, abstracts and systematic and other review papers;
- studies not looking at the accuracy, reliability, consistency or validity of pedometers;
- unpublished or non-English language publications;
- studies with adults or people with medical conditions as subjects.

Data extraction and assessment

The data extracted from each paper included:

- study design;
- sample size;
- population characteristics;
- main outcomes [r and interclass correlation (ICC) values];
- relevant limitations;

The effectiveness of pedometers among children was addressed under the following headings:

Validity

Convergent validity refers to the extent to which the output of one instrument correlates with the output of other instruments that should, theoretically, be measuring the same exposure of interest.[15] In this instance, the convergent validity of a pedometer can be ascertained by comparing it to self-report questionnaires, heart rate monitors and accelerometers—all of which measure physical activity. Criterion validity refers specifically to the comparison of a method to the most valid assessment method available, the gold or criterion standard.[15] There is currently no universally agreed upon method for physical activity measurement. There is a valid argument for a number of different methods, mainly direct observation, doubly labelled water technique or indirect calorimetry.[16] It is important for researchers to consider what element of physical activity they wish to assess. Direct observation is a better reference point in terms of step count measurement[17], whereas the other two methods are more suited to the measurement of energy expenditure.

Validity can be quantified using Pearson's product-moment correlation coefficient (r). Other output measures of validity are percentage accuracy/error and ICC. A general guideline is that an ICC ≥ 0.75 is deemed good.[18]

Reliability

This covers a number of similar concepts. Reproducibility or repeatability refers to the extent to which a pedometer is free of measurement error.[19] This covers both intra-instrument reliability, which is the test–retest reliability of a pedometer, and inter-instrument reliability, which refers to the variability between pedometers.

Feasibility

This refers to the cost involved and skill required when using a pedometer. Feasibility also includes acceptability, the tolerance of the device and amount of lost or missing data as a result of malfunctioning and any other limitations involved. Feasibility also covers the issue of reactivity, a change in normal behaviour as a result of having to wear a pedometer.[20] True reactivity can only be gauged by knowingly and covertly measuring activity and comparing. Given this is practically unfeasible, most studies investigate the difference between the first and subsequent days of activity measurement.

Results

Search strategy

The initial electronic search using the three main keywords, including variations led to the identification of 178 possible papers. Upon applying the inclusion and exclusion criteria as stated in the methodology, 38 articles remained. Fifteen papers were duplicates. Finally, upon reading through all of these papers and checking their bibliographies for other relevant papers, 25 papers were deemed suitable for this literature review and these are summarized in Table 1 below.

Across the 25 studies reviewed here, a total of 13 692 children and adolescents were included as subjects. They ranged from 4 to 20 years of age.

Criterion validity

Twelve studies investigated the criterion validity of pedometers by comparing their performance to that of direct observation.[21–33]

Beets *et al.*[21] compared the accuracy of four different types of pedometers to direct observation by looking at the two across five speed grades and for all four pedometer brands used, the accuracy improves with increasing speed (ICC = 0.225–0.99). When asked to walk at a normal pace, no longer on the treadmill, subjects walked at $\sim$67 $\mathrm{m \cdot min^{-1}}$, the third of five paces. Duncan *et al.*[27] presented similar findings, pedometers performing well at moderate and fast paces (0.7% measurement error) but underperformed at slower walking speeds (20% measurement error). Mitre *et al.*[23] recorded a correlation between the pedometer-determined activity and directly observed activity ranging from 50% accurate to 75% accurate, improving with treadmill speed in all cases.

In a free-living environment, the correlation between pedometers and direct observation ranged from $r = 0.8$[29] to ICC = 0.985[21] depending on the specific environment and activity that subjects were engaged in. In three studies carried out by Scruggs *et al.*[26,31,33] correlation coefficients with direct observation in a free-living environment ranged from 0.74 to 0.92. By investigating free-living physical activity as determined by a pedometer, Oliver *et al.*[25] found that it correlated poorly with direct observation. As a result, they do not recommend pedometers as an accurate measure of physical activity in children. McDonald *et al.*[22] found pedometers to be 99.87% accurate when compared with 10 min of self-paced walking. Kilanowski *et al.*[29] investigated the validity of pedometers in both a classroom and recreational setting. The findings showed a high correlation with direct observation in both instances—$r = 0.8$ (classroom), $r = 0.96$ (recreation).

Table 1 Studies investigating the validity and reliability of pedometers.

Reference	Study sample (n, age)	Methods	Results
Barfield *et al.*[42]	71	5 days in-school activity—two pedometers (Yamax SW200) on hips	Inter-instrument reliability: ICC = 0.96–0.99
Beets *et al.*[21]	20, (5–11)	Three laps walking—two pedometers (Yamax SW200, Walk4life LS2505) versus direct observation	Walking: Validity versus d/o: ICC ≥ 0.985 Bilateral variability: ICC ≥ 0.33–0.99 with increasing speed
		5 speeds on treadmill—four pedometers versus direct observation	Treadmill: Validity versus d/o: ICC ≥ 0.225–0.99 with increasing speed
Beets *et al.*[44]	141, (8–10)	7 days activity—pedometer (Walk4life LS2505) versus self-report questionnaire	Reactivity: 78.5% of children noted reactivity, 47.3% of parents
Cardon and De Bourdeaudhuij[40]	92, (6–12)	6 days activity—pedometer (Yamax SW200) versus questionnaire	Validity: $r = 0.39$
Craig *et al.*[43]	10 275, (5–19)	7 days activity—pedometer (Yamax SW200)	No reactivity between Day 1 and 2 1 day provided reliability (ICC = 0.79) and validity (absolute % error = 2.5%)
Duncan *et al.*[27]	85, (8–11)	3 speeds on treadmill—two pedometers (NL 2000) versus direct observation	Error versus d/o: 20–0.7% improves with increasing speed
Eston *et al.*[36]	30, (8–11)	4 speeds on treadmill and play—one pedometer (Yamax SW200), two triaxial accelerometers, HR monitor	Validity versus HR: Treadmill: ICC ≥ 0.816 Play: ICC ≥ 0.883
Graser *et al.*[28]	77, (10–12)	2 phases on treadmill (with and without belt), shake test—five pedometers (Walk4life LS2505)	Accuracy: 99% Right side deemed best position
Jago *et al.*[35]	78, (11–15)	3 speeds on treadmill—three pedometers (Yamax SW200), uniaxial accelerometer	Reliability: ICC ≥ 0.51–0.92 Bilateral variability: ICC ≥ 0.73–0.8 Validity versus accelerometer: $r = 0.6$
Kilanowski *et al.*[29]	10, (7–12)	Recreation and classroom—pedometer (Yamax SW200), triaxial accelerometer, d/o	Validity versus accelerometer: $r = 0.99/0.5$ for rec/class Validity versus d/o: $r = 0.96/0.8$ for rec/class
McDonald *et al.*[22]	97, (6–20)	3 days activity/treadmill—one HR monitor, one pedometer (Stepwatch 2)/direct observation	Validity versus HR: $r = 0.49$ Validity versus d/o: 99.7% accurate

Michaud *et al.*[38]	233, (11–15)	7 days activity—pedometer (Pedoboy), self-report	Validity versus self-report: $r = 0.15$
Mitre *et al.*[28]	27, (11)	4 speeds on treadmill—four pedometers (Yamax SW200), two accelerometers, direct observation	Validity versus d/o: 50–75% accurate, improving with increasing speed
Nakae *et al.*[24]	394, (7–12)	3 speeds on treadmill—pedometer (Kenz Lifecorder, Omron HJ7001T), direct observation	Validity versus d/o: Significant measurement error for pedometers
Oliver *et al.*[25]	13, (4)	Free play—pedometer (Yamax SW200), direct observation 3-speed walking—pedometer, direct observation	Validity versus d/o: Significant measurement error for pedometers
Ozdoba *et al.*[20]	45, (9–10)	4 days activity on 2 occasions—sealed versus unsealed pedometer (Yamax SW200)	Reliability: ICC = 0.86–91 (sealed) and 0.85–0.91 (unsealed)—no reactivity
Ramirez-Marrero *et al.*[37]	12	7 days of activity—pedometer (Yamax SW200), triaxial accelerometer, questionnaire and doubly labelled water	Validity versus accelerometer: $r = 0.88$ Validity versus DLW: $r = 0.67$
Rowe *et al.*[46]	299, (10–14)	7 days of activity—pedometer (Yamax SW200)	Reliability: $r = 0.69$–0.79—no reactivity
Rowe *et al.*[41]	296, (11–13)	6 days activity—self-report questionnaire versus pedometer (Yamax SW200)	Validity: $r = 0.17$—ped provided external validity
Scruggs *et al.*[26]	288, (11–13)	PE class—pedometer (Yamax SW701, Walk4life LS2505) versus direct observation	Pedometer validity versus d/o: $r = 0.85$–0.98
Scruggs *et al.*[33]	257	PE class—pedometer (Yamax SW651) versus direct observation	Accuracy: 98% Validity versus d/o: $r = 0.84$
Scruggs *et al.*[31]	369, (7–8)	PE class—pedometer (Yamax SW200) versus direct observation	Validity versus d/o: $r = 0.74$–0.86
Strycker *et al.*[39]	367, (10–14)	7 days activity—pedometer (Yamax SW701), self-report	Validity versus self-report: $r = 0.04$ (at school), 0.15 (non-school), 0.25 (vigorous PA)
Treuth *et al.*[36]	68, (8–9)	4 days activity—uniaxial accelerometer, pedometer (Yamax SW200), two self-report	Reliability: ICC ≥ 0.08 Validity versus accelerometer: $r = 0.47$
Weston *et al.*[32]	48, (12–14)	1 day recall versus pedometer and uniaxial accelerometer	Validity: $r = 0.88$, pedometer provided external validity

Convergent validity

Three studies measured the convergent validity of pedometers against heart-rate monitors.[22,32,34] Six studies measured the convergent validity of pedometers against accelerometers[29,32,34–37] and five studies measured the validity of pedometers against self-report measures.[36,38–41]

The level of correlation between pedometers and accelerometers ranged from 0.47[36] to 0.99[29] depending on environment and type of activity. Kilanowski *et al.*[29] carried out testing in both a classroom and recreational setting, and found that pedometers and accelerometers were more strongly correlated in the recreational setting ($r = 0.98$) than in the classroom environment ($r = 0.5$), but combined results showed an even stronger correlation ($r = 0.99$). Jago *et al.*[35] measured only moderate and vigorous activity levels when comparing the accuracy of pedometers and accelerometers. In doing so, the author found a positive correlation between both methods ($r = 0.6$), regardless of whether subjects were walking, walking fast or running.

Correlations with heart-rate monitors ranged from $r = 0.49$[22] to ICC ≥ 0.83, again dependant on environment (treadmill versus free living) and activity type. Eston *et al.*[34] also compared the accuracy of pedometers with heart-rate monitors and correlations were established from treadmill activity and unregulated play activity. A stronger correlation was found during unregulated play ($r = 0.883$, 0.865, 0.762) than during treadmill activity ($r = 0.816$, 0.712, 0.319). The study also found that, along with the HR monitor, the pedometer was strongly correlated with SVO_2. McDonald *et al.*[22] also concluded that a pedometer was a valid method of physical activity assessment in children, based on a moderate correlation between pedometers and HR monitors ($r = 0.49$).

Correlations between pedometer-determined activity and activity levels as determined by self-report and questionnaire ranged from $r = 0.04$[39] to 0.39.[40] One study found a correlation between pedometers and the doubly labelled water method of $r = 0.88$.[37]

Reliability

The inter- and intra-unit reliability as well as inter-brand reliability of pedometers was investigated in eight of the studies.[21,23,28,34–36,42,43]

Barfield *et al.*[42], Beets *et al.*[21] and Jago *et al.*[35] looked at reliability of pedometers with specific reference to bilateral variability—right versus left placement. Beets *et al.*[21] did so using four different brands of pedometer and at five different speeds. Bilateral variability travelled in range from ICC ≥ 0.33 to 0.99 depending on activity and speed of movement, increasing with speed. During walking, walking fast and running tests, Jago *et al.*[35] had subjects wear three identical pedometers around their waists. Jago *et al.* found that the degree of reliability among pedometers ranged from ICC $\geq$0.51 to 0.92 and inter-unit reliability levels ranged from 0.73 to 0.8.[35] Once again, this variance in range was due to type of activity, fast walking deemed more reliable than running. Barfield *et al.*[42] recorded a very small range in reliability (ICC = 0.96–0.99), regardless of the setting.

Graser *et al.*[28] had subjects wear five pedometers at once, three around the waist and two on the thigh. Mean percentage error at each site was established by direct observation. The right side of the waist was deemed the site with the lowest rate of pedometer inaccuracy (5.3%). Mitre *et al.*[23] and Eston *et al.*[34] also experimented by using more than one pedometer at a time. Mitre *et al.*[23] discovered a variation of between 3 and 10% depending on what side of the body the pedometer was worn. Both studies concluded that the use of just one pedometer, worn on the right side of the hip, was sufficient to give a valid reading of a child's physical activity levels.

Feasibility

The feasibility of pedometers, specifically looking at reactivity, was assessed in three studies.[20,43–45] Ozdoba *et al.*[20], Craig *et al.*[43] and Rowe *et al.*[45] gauged reactivity based on the hypothesis that if the observed activity on the first day(s) is not significantly different from activity levels on the last day(s), then reactivity has not taken place. In the Rowe *et al.*[45] study, reliability improved as the number of days increased ($r = 0.59$–0.81). Ozdoba *et al.*[20] noted that this parameter varied from an ICC of 0.8–0.91, whereas Craig *et al.*[43] recorded an ICC ranging from 0.79 to 0.92. In the other study measuring reactivity, it took place for 79 and 47% of children, as observed by the child and parent, respectively.

Investigating the benefit of sealing pedometers, Ozdoba *et al.*[20] noted that seven unsealed pedometers had been tampered with and reset, compared with zero sealed pedometers.

Discussion

Criterion validity

The most suitable gold standard method of physical activity, and specifically step count measurement, is direct observation. However, accurate direct observation over the course of 1 day would require the researcher to record every moment of a 24 h period in close proximity of the subject. This is very impractical in normal living circumstances and as a result, researchers try to find a more controlled environment to carry out observation. With this in mind, a more favourable environment for physical activity assessment by direct observation is on a treadmill. As a result, the criterion validity of different methods of physical activity assessment is often measured via a treadmill test. This review covers seven studies that assessed the validity of pedometers in this way.[21–25,27,28]

Beets *et al.*[21] and Duncan *et al.*[27] both noted that the accuracy of pedometers improved with increasing speed. Although the pedometer underestimated physical activity at a slower pace, this is an uncharacteristically slow pace for a child to walk at and not representative of their behaviour in free-living environment. Duncan *et al.*[27] proposed that this underperformance could be explained by the mechanics of the pedometer. A force of 0.35 g is required to register a step on a pedometer.[46] Given that, at the slower paces, children are more inclined to take long, slow and controlled steps, they may not be achieving the required g-force, a theory supported by the findings of a recent study by Duncan *et al.*[27] As a result, pedometers underestimate physical activity levels when compared with direct observation. Mitre *et al.*[23] and Nakae *et al.*[24] also found that decreasing speed leading to decreasing accuracy could be attributed to insufficient acceleration and displacement.

Given that the pedometers were deemed valid indicators of physical activity at moderate and fast speeds, the practical significance of the poor correlations at lower speeds may not be relevant. First, children do not travel at such a slow pace when walking. Second, it is moderate and vigorous activity that is required for children to incur health benefits, not slow walking. Therefore, it is most important that moderate and vigorous activity should be tracked by the pedometer. Despite the fact that pedometers were consistently inaccurate at the slowest speeds, the accumulated evidence suggests that they are highly reliable at more practical speeds.

However, the author does note that poor correlation may be in part due to the use of direct observation (Children's Activity Rating Scale), which was designed to measure energy expenditure, not physical activity. These are two very different variables and it is worth remembering that the sole function of a pedometer is to measure step counts, not energy expenditure. Also, the feasibility of direct observation in a free-living environment is questionable and may have affected the results.

McDonald *et al.*[22], Kilanowski *et al.*[29] and Scruggs *et al.*[33] recorded high levels of criterion validity during self-paced walking, a recreational setting and PE class, respectively. The consistent accuracy of pedometer data compared with direct observation in these and other studies,[26,28,30] even in a free-living environment, gives further weight to the argument that it is a valid method of activity measurement. In both recreational and more sedentary (classroom) situations, pedometers have the capacity to gauge both children's activity and inactivity, intimating that pedometers are highly representative in normal free-living conditions.

Convergent validity

As expected, subjects were much more active in the recreational environment than in the classroom, where they would be obliged to remain seated and predominantly sedentary. It is important to understand the nature of children's behaviour in this setting—short bursts of high levels of activity combined with longer periods of low-intensity activity and sedentary behaviour.[47] As a result, it is understandable that the pedometer is less accurate in a classroom situation, children are mainly seated and little vertical movement takes place. This means that the pedometer does not record any g-force. With this in mind, the author suggests that pedometers are an accurate method of determining moderate to vigorous activity, but not lower intensity activity. It is this sort of moderate and vigorous activity that is most important to track and promote in children and adolescents.

Treuth *et al.*[36] found pedometer-determined activity to be only moderately correlated with accelerometers following a 4-day testing period. The pedometer used in this study required the subject to record their total step counts on a daily basis, and a lack of cooperation may explain the poorer association. The majority of pedometers now have the capacity to store the daily step count over a number of days without any reliance on the subject to account for such limitations.

Overall, pedometers perform very favourably when compared with accelerometers. The comparative mechanical limitation of pedometers (measuring motion in one plane only) is a minor limitation, but the measurement of moderate and vigorous ambulatory motion is similar for both devices. Ramirez-Marrero *et al.*[37] recorded a stronger correlation between pedometers and accelerometers ($r = 0.88$) than between pedometers and the doubly labelled water method ($r = 0.67$). This stands to reason as the doubly labelled water method is more suited to recording energy expenditure than step counts.

The comparison of pedometers with similar methods of physical activity measurement consistently shows that pedometers are just as effective as more widely validated methods like heart-rate monitoring and accelerometry. Some concern has been voiced at the inability of pedometers to measure sedentary behaviour, and this is deemed an advantage of accelerometry. But the studies mentioned here provide encouraging evidence of pedometers being as effective as accelerometers in a sedentary, classroom setting.

Reliability

The accurate inter-unit agreement implied that pedometers are a reliable form of physical activity measurement and that the side of the body that the pedometer is worn is not relevant.

There were no significant differences between sites in these studies, suggesting that all were viable sites to validly establish activity levels in children. Even so, Graser *et al.*[28] recommended the right side of the waist as the optimum site for pedometer placement, solely because it allows the subject to read their step count. It seems that hip placement seems the most practical site for a pedometer. This ensures that ambulatory activity is recorded. Placement on the ankle or leg would cause a pedometer to record cycling and other similar movements. Although beneficial as a more accurate indication of physical activity, this would no longer solely constitute step counts. Widespread agreement and instruction on the proper placement of a pedometer remains relatively sparse, and more research is required to establish an accepted protocol across all studies. Such agreement would allow for confident comparison of results between studies.

Another important issue that needs to be considered when discussing reliability is sensitivity. This is the vertical threshold required to administer one step. Differences in sensitivity from one pedometer to the next may lead to variations in the accuracy of pedometers. For example, a CSA pedometer requires 0.3 g to register a step, whereas a YX200 pedometer requires 0.35 g, and this may explain the difference found between these two types of pedometers in a study by Tudor-Locke *et al.*[15] Increased sensitivity means you can record slow steps, but you also record much more non-ambulatory movement like fidgeting and twisting.

The effect of body composition, and particularly obesity, on pedometer accuracy is another important reliability issue. A pedometer should ideally be placed in the vertical plane to ensure it registers displacement from ambulatory movement.[28] This placement could potentially be affected by excess abdominal adiposity.[15] However, both Duncan *et al.*[27] and Abel *et al.*[48] failed to find a significant difference in pedometer bias according to body composition. Both studies compared step counts according to waist circumference, while Duncan *et al.*[27] also compared BMI and percentage body fat. Duncan *et al.*[27] did note that pedometer bias was significantly affected by the pedometer tilt-angle.

Although an important limitation of pedometer use, non-ambulatory movement like cycling and swimming is largely unreported in the literature. This is a significant issue that requires further research.

Feasibility

Pedometers are cheap and easy to use for both researchers and lay people. No limitations were mentioned in any of the studies citing an inability to operate them, or complaining about large costs incurred. With this in mind, pedometers are practical for use in large studies of children's activity.

Compliance is a particularly important feasibility issue related to the use of pedometers in large-scale field studies. The largest study reviewed here, Craig *et al.*[43] highlighted a 97% compliance rate as one of the main achievements of the study. Elsewhere, compliance remains an under-reported but important issue. In the future, studies should include information on the rate of compliance and how this was achieved. This will allow other researchers to improve their methodology to ensure the highest possible levels of adherence in their pedometer studies and will also allow for easier comparison between studies.

Regarding reactivity, there is a concern that if someone is aware that their activity levels are being monitored, they will become more active. This may be particularly true for children and adolescents, given that they are inherently competitive. By comparing the effectiveness of sealed and unsealed pedometers, Ozdoba *et al.*[20] found no evidence of reactivity in either case. A significant difference occurred between days on one occasion, but given that this was probably due to the fact that it rained on this day, it was not deemed to represent reactivity.

Using just unsealed pedometers, both Rowe [45] and Craig [43] came to a similar conclusion. The fact that there was no significant difference in mean step counts between Day 1 and 2 intimates that children did not alter their behaviour because they were wearing pedometers. The debate about whether to seal pedometers centres in relation to that of an unsealed pedometer might promote reactivity. Both of these studies suggest that neither sealed nor unsealed pedometers are affected by reactivity among children.

As previously mentioned, the use of pedometers in a controlled clinical setting, such as on a treadmill, differs greatly from their use in a more realistic daily situation. With regard to validity, it is much easier to effectively gauge the accuracy and reliability of pedometers on a treadmill by comparing them to direct observation. This is not the case in a free-living environment, where accurate direct observation is very difficult, if not unfeasible. Observing step counts on a treadmill simply involves the researcher counting consistently step by step. In a free-living environment, the notion of 'one step' is much more ambiguous. In a classroom, a child may be seated but moving from side to side. Playing outside, they may hop, skip, jump, sidestep, run, walk and crawl all in a short period of time. Through direct observation, it becomes very difficult to discern whether or not any or all of these motions, which do constitute physical activity, are considered the equivalent of 'one step' by the researcher or by the pedometer.

Using a pedometer in a free-living environment presents a number of other limitations. If a child is asked to walk on a treadmill for any amount of time, possible complications like defining outliers and accounting for missing data are of no concern. Usually in this type of study, subjects are only asked to walk for a few minutes, and the researcher puts on and takes off the pedometer immediately before and after testing. Given that a researcher is constantly present to monitor and instruct the subject, the pedometer should not be interfered with in any way.

In a free-living environment, children may be given a pedometer to wear for 7 days without any supervision. In this instance, children can lose, break or manipulate their pedometers. This results in missing data. If the pedometer is unsealed, children have the capacity to reset them, as observed by Ozdoba *et al.*[20] This is of practical importance when planning a large-scale pedometer study, as sealing pedometers, although beneficial, is often very time-consuming and may be unfeasible.

Only one study[45] covered the issue of outliers in any detail, proposing outliers of 1000–30 000 for children. These limits were established primarily by establishing a reasonable range for step count scores based on prior testing experiences and hypothetical situations of extremely active and inactive children. The establishment of outliers for specific populations, both children and adults, is an important and under-reported issue that needs to be explored further.

Conclusion

A number of studies have investigated the inter- and intra-unit reliability of pedometers, as well as their criteria and convergent validity, as established through comparison with direct observation, accelerometers and heart-rate monitors. This paper reviewed these studies to establish the utility of pedometers as a determinant of physical activity among children and adolescents.

It is quite common for studies of this nature to investigate the merits of different methods by measuring physical activity levels as established by a subject walking on a treadmill. In doing so, some studies have proposed that pedometers are a valid method of physical activity measurement, particularly at moderate and fast speeds. However, children and adolescents do not do their physical activity on a treadmill. Field studies, with the validity of pedometers being assessed in free-living conditions, are a much more relevant indicator of activity levels. A number of such studies have been carried out and established that pedometers are reliable and valid measures of physical activity levels for children and adolescents.

Pedometers do have limitations, specifically with regard to the measurement of sedentary behaviour and accounting for missing data. However, this is largely accounted for by the nature of children's behaviour, short intense bursts of activity followed by longer periods of inactivity. Encouraging results also show high correlations between pedometers and both direct observation and accelerometers in low-intensity and sedentary environments. Positive levels of inter- and intra-pedometer reliability promote the effectiveness of pedometers. Given they are relatively cheap and easy to use, pedometers can potentially be used in large-scale epidemiological studies and interventions, offering motivational and educational support. This review concludes that pedometers can effectively be utilized as a valid determinant of physical activity levels among children and adolescents.

Funding

PhD studentship.

References

1 *Health Survey for England 2008* Department of Health, 2008.
2 Wang Y, Beydoun MA, Liang B *et al.* Will all Americans become overweight or obese? Estimating the progression and cost of the US obesity epidemic. *Obesity* 2008;16:2323–30.
3 CDC. *Overweight among US children and adolescents. National Health and Nutritional Survey*, 2000. [cited 2009 11.03]; http://www.cdc.gov/nchs/nhanes.htm.
4 Martin J, Hernandez L, Gonzalez M *et al.* Trends in childhood and adolescent obesity prevalence in Oviedo (Asturias, Spain) 1992–2006. *Acta Paediatr* 2008;97:955–8.
5 Matthiessen J, Velsing Groth M, Fagt S *et al.* Prevalence and trends in overweight and obesity among children and adolescents in Denmark. *Scand J Public Health* 2008;36:153–60.
6 Freedman DS, Wang J, Ogden CL *et al.* The prediction of body fatness by BMI and skinfold thicknesses among children and adolescents. *Ann Hum Biol* 2007;34:183–94.
7 Hedley AA, Ogden CL, Johnson CL *et al.* Prevalence of overweight and obesity among US children, adolescents, and adults, 1999–2002. *JAMA* 2004;291:2847–50.

8 Goran MI. Energy expenditure, body composition, and disease risk in children and adolescents. *Proc Nutr Soc* 1997;56:195–209.

9 Andersen RE, Crespo C, Bartlett S *et al.* Relationship of physical activity and television watching with body weight and level of fatness among children: results from the Third National Health and Nutrition Examination Survey. *JAMA* 1998;279:938–42.

10 Tudor-Locke C, Williams JE, Reis JP, Pluto D *et al.* Utility of pedometers for assessing physical activity: construct validity. *Sports Med* 2004;34:281–91.

11 Spiegelman BM, Flier JS. Obesity and the regulation of energy balance. *Cell* 2001;104:531–43.

12 Reichert FF, Baptista Menezes AM, Wells JCK *et al.* Physical activity as a predictor of adolescent body fatness: a systematic review. *Sports Med* 2009;39:279–94.

13 Tudor-Locke C, McClain JJ, Hart TL *et al.* Pedometry methods for assessing free-living youth. *Res Q Exerc Sport* 2009;80:175–84.

14 de Vries SI, Bakker I, Hopman-Rock M *et al.* Clinimetric review of motion sensors in children and adolescents. *J Clin Epidemiol* 2006;59:670–80.

15 Tudor-Locke C, Williams JE, Reis JP, Pluto D *et al.* Utility of pedometers for assessing physical activity: convergent validity. *Sports Med* 2002;32:795–808.

16 Mahar M, Rowe D. In Welk GJ (ed) *Criterion-Related Evidence, in Physical Activity Assessment for Health-Related Research.* Champaign, IL: Human Kinetics, 2002, 62.

17 Sirard JR, Pate RR. Physical activity assessment in children and adolescents. *Sports Med* 2001;31:439–54.

18 Portney L, Watkins M. *Statistical Measures of Reliability, in Foundations of Clinical Research: Applications to Practice.* NJ: Prentice-Hall, 2000, 565.

19 de Vet H, Terwee C, Bouter L. Current challenges in clinimetrics. *J Clin Epidemiol* 2003;56:1137–41.

20 Ozdoba R, Corbin C, Le Masurier G. Does reactivity exist in children when measuring activity levels with unsealed pedometers? *Pediatr Exerc Sci* 2004;16:158–66.

21 Beets MW, Patton MM, Edwards S. The accuracy of pedometer steps and time during walking in children. *Med Sci Sports Exerc* 2005;37:513–20.

22 McDonald CM, Widman L, Abresch RT *et al.* Utility of a step activity monitor for the measurement of daily ambulatory activity in children. *Arch Phys Med Rehabil* 2005;86:793–801.

23 Mitre N, Lanningham-Foster L, Foster R, Levine JA *et al.* Pedometer accuracy for children: can we recommend them for our obese population? *Pediatrics* 2009;123:e127–31.

24 Nakae S, Oshima Y, Ishii K. Accuracy of spring-levered and piezo-electric pedometers in primary school Japanese children. *J Physiol Anthropol* 2008;27:233–9.

25 Oliver M, Scholfield GM, Kolt GS, Schluter PJ *et al.* Pedometer accuracy in physical activity assessment of preschool children. *J Sci Med Sport* 2007;10:303–10.

26 Scruggs PW. Quantifying activity time via pedometry in fifth- and sixth-grade physical education. *J Phys Act Health* 2007;4:215–27.

27 Duncan JS, Schofield G, Duncan EK, Hinckson EA *et al.* Effects of age, walking speed, and body composition on pedometer accuracy in children. *Res Q Exerc Sport* 2007;78:420–8.

28 Graser SV, Pangrazi RP, Vincent WJ. Effects of placement, attachment, and weight classification on pedometer accuracy. *J Phys Act Health* 2007;4:359–69.

29 Kilanowski CK, Consalvi AR, Epstein LH. Validation of an electronic pedometer for measurement of physical activity in children. *Pediatr Exerc Sci* 1999;11:63–8.

30 Scruggs PW. A comparative analysis of pedometry in measuring physical activity of children. *Med Sci Sports Exerc* 2007;39:1837–46.

31 Scruggs PW, Beveridge SK, Eisenman PA *et al.* Quantifying physical activity via pedometry in elementary physical education. *Med Sci Sports Exerc* 2003;35:1065–71.

32 Weston AT, Petosa R, Pate RR. Validation of an instrument for measurement of physical activity in youth. *Med Sci Sports Exerc* 1997;29:138–43.

33 Scruggs PW, Beveridge SK, Watson DL, Clocksin BD *et al.* Quantifying physical activity in first through fourth grade physical education via pedometry. *Res Q Exerc Sport* 2005;76:166–75.

34 Eston RG, Rowlands AV, Ingledew DK. Validity of heart rate, pedometry, and accelerometry for predicting the energy cost of children's activities. *J Appl Physiol* 1998;84:362–71.

35 Jago R, Watsin K, Baronowski J *et al.* Pedometer reliability, validity and daily activity targets among 10- to 15-year-old boys. *J Sports Sci* 2006;24:241–51.

36 Treuth MS, Sherwood NE, Butte NF *et al.* Validity and reliability of activity measures in African-American girls for GEMS. *Med Sci Sports Exerc* 2003;35:532–9.

37 Ramirez-Marrero FA, Smith BA, Sherman WM, Kirby TE *et al.* Comparison of methods to estimate physical activity and energy expenditure in African American children. *Int J Sports Med* 2005;26:363–71.

38 Michaud P, Cauderay M, Narring F, Schutz Y *et al.* Assessment of physical activity with a pedometer and its relationship with VO2max among adolescents in Switzerland. *Soz Praventivmed* 2002;47:107–15.

39 Strycker LA, Duncan SC, Chaumeton NR *et al.* Reliability of pedometer data in samples of youth and older women. *Int J Behav Nutr Phys Act* 2007;4:4.

40 Cardon G, De Bourdeaudhuij I. A pilot study comparing pedometer counts with reported physical activity in elementary schoolchildren. *Pediatr Exerc Sci* 2004;16:355–67.

41 Rowe DA, Raedeke TD, Wiersma LD, Mahar MT *et al.* Investigating the youth physical activity promotion model: internal structure and external validity evidence for a potential measurement model. *Pediatr Exerc Sci* 2007;19:420–35.

42 Barfield JP, Rowe DA, Michael TJ. Interinstrument consistency of the Yamax Digi-Walker pedometer in elementary school-aged children. *Meas Phys Edu Exerc Sci* 2004;8:109–16.

43 Craig CL, Tudor-Locke C, Cragg S, Cameron C *et al.* Process and treatment of pedometer data collection for youth: The Canadian Physical Activity Levels Among Youth Study. *Med Sci Sports Exerc* 2010;42:430–5.

44 Beets M, Eilert A, Pitetti K, Foley J *et al.* Student and parent self-report changes in physical activity behavior while wearing an unsealed pedometer. *Pediatr Exerc Sci* 2006;18:492–9.

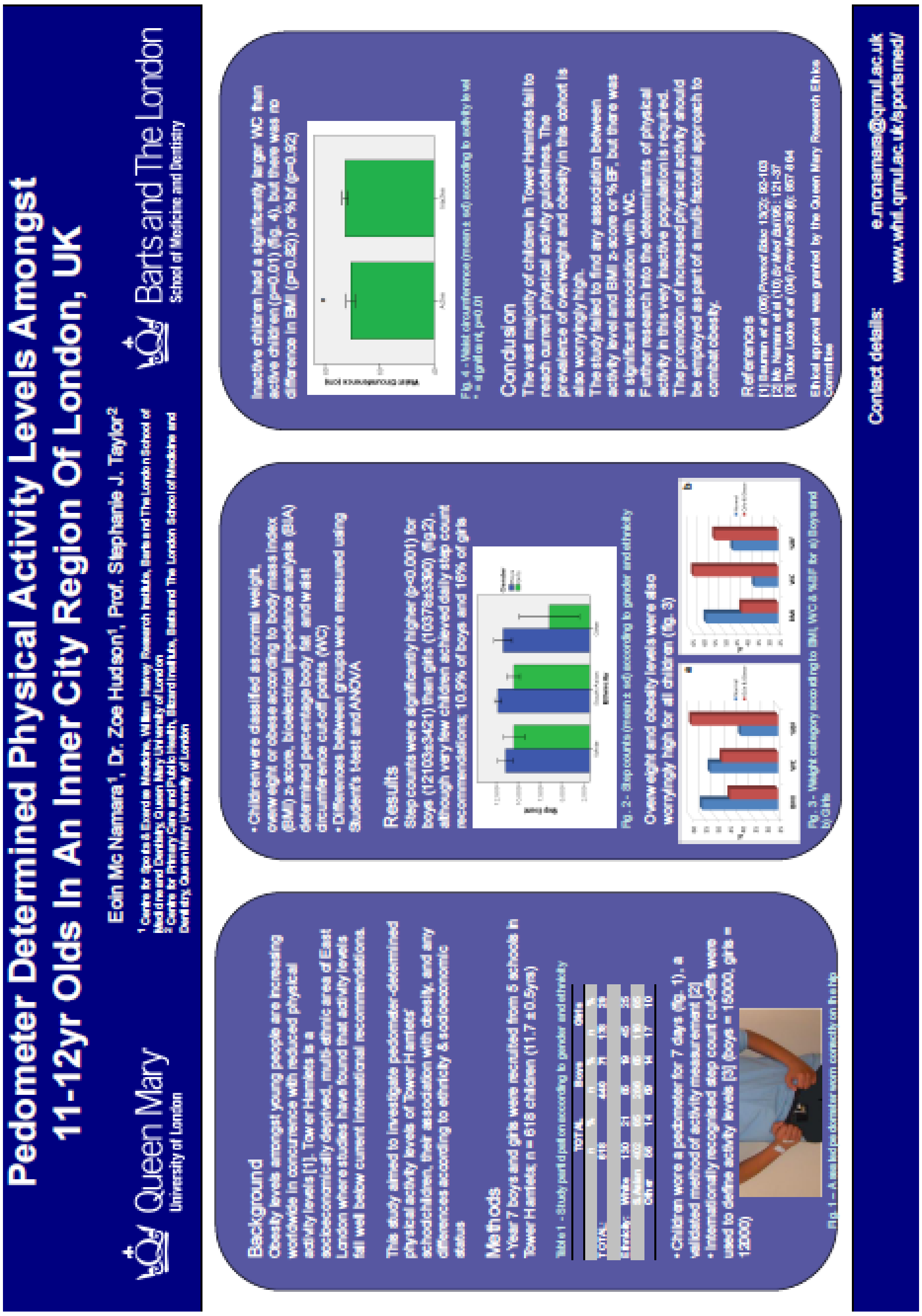
45 Rowe DA, Mahar MT, Raedeke TD, Lore J *et al.* Measuring physical activity in children with pedometers: reliability, reactivity, and replacement of missing data. *Pediatr Exerc Sci* 2004;16:343–54.

46 Melanson E, Knoll J, Bell M *et al.* Commercially available pedometers: consideration for accurate step counting. *Prev Med* 2004;39:361–8.

47 Sallo M, Silla R. Physical activity with moderate to vigorous intensity in pre-school and first-grade children. *Pediatr Exerc Sci* 1997;4:44–54.

48 Abel MG, Hannon JC, Eisenman PA *et al.* Waist circumference, pedometer placement and step count accuracy in youth. *Res Q Exerc Sport* 2009;80:434–44.

b)



Pedometer Determined Physical Activity Levels Amongst 11-12yr Olds In An Inner City Region Of London, UK
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Background
Obesity levels amongst young people are increasing worldwide in concurrence with reduced physical activity levels [1]. Tower Hamlets is a socioeconomically deprived, multi-ethnic area of East London where studies have found that activity levels fall well below current international recommendations.
This study aimed to investigate pedometer-determined physical activity levels of Tower Hamlets' schoolchildren, their association with obesity, and any differences according to ethnicity & socioeconomic status
Methods
• Year 7 boys and girls were recruited from 5 schools in Tower Hamlets; n = 618 children (11.7 ±0.5yrs)
Table 1 - Study participation according to gender and ethnicity
• Children wore a pedometer for 7 days (fig. 1), a validated method of activity measurement [2]
• Internationally recognised step count cut-offs were used to define activity levels [3] (boys = 15000, girls = 12000)
Fig. 1 – A sealed pedometer worn correctly on the hip
• Children were classified as normal weight, overweight or obese according to body mass index (BMI) z-score, bioelectrical impedance analysis (BIA) determined percentage body fat and waist circumference cut-off points (WC)
• Differences between groups were measured using Student's t-test and ANOVA
Results
Step counts were significantly higher (p<0.001) for boys (12103±3421) than girls (10378±3390) (fig.2), although very few children achieved daily step count recommendations; 10.9% of boys and 16% of girls
Fig. 2 - Step counts (mean ± sd) according to gender and ethnicity
Overweight and obesity levels were also worryingly high for all children (fig. 3)
Fig. 3 - Weight category according to BMI, WC & %BF for a) Boys and b) Girls
Inactive children had a significantly larger WC than active children (p=0.01) (fig. 4), but there was no difference in BMI (p=0.82)) or % bf (p=0.92)
Fig. 4 - Waist circumference (mean ± sd) according to activity level
* = significant, p=0.01
Conclusion
The vast majority of children in Tower Hamlets fail to reach current physical activity guidelines. The prevalence of overweight and obesity in this cohort is also worryingly high.
The study failed to find any association between activity level and BMI z-score or %BF, but there was a significant association with WC.
Further research into the determinants of physical activity in this very inactive population is required.
The promotion of increased physical activity should be employed as part of a multi-factorial approach to combat obesity.
References
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This work is supported by the Wellcome Trust [grant reference WT084686MA] and Medical Research Council [G0400546].
The Millennium Cohort Study is supported by the Economic and Social Research Council and a consortium of government funders.

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Title: The validity of pedometers as a measure of physical activity in adolescents: a review of the literature

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Background/aims: The effective measurement of physical activity among young people, for both intervention and observational studies is of great importance. Pedometers provide a cheap, easy to use, objective measurement of step counts and are practical for use in large-scale epidemiological studies. However, their effective use is dependent on pedometers being validated as accurate measurement tools. This paper reviews studies investigating the validity, reliability and feasibility of pedometers as determinants of physical activity among children and adolescents.

Methods: A literature search was performed in PubMed, Web of Science, PsycINFO, CINAHL and SportDISCUS for studies reporting on the validity, reliability, consistency or accuracy of pedometers amongst children and adolescents.

Results: In total 25 papers were included in the review. Criterion validity has been established through a number of studies, pedometers correlating highly with direct observation (ICC=0.225-0.99), improving with increasing walking speed. Convergent validity has also been established against heart-rate monitors (r=0.49-0.88) and accelerometers (r=0.47-0.99).

Intra- instrument (ICC=0.51-0.92) and inter-instrument reliability (ICC=0.73-0.8) were both consistently high across studies. Few studies reported feasibility issues of pedometer use in children, particularly compliance, the treatment of missing data and reactivity, a change in normal behaviour as a result of having to wear a pedometer.

Conclusion: This review shows that pedometers are a reliable and valid measure of activity in adolescent populations. Given their low cost and validated performance, pedometers can be effectively employed to measure physical activity among children and adolescents, particularly in large-scale epidemiological studies. There remains a need for accepted outliers and proper protocol regarding missing data.

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Physical activity in adolescents in an Olympic borough prior to the London 2012 Olympic Games

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Overweight and obesity continues to be an escalating epidemic in children. Tower Hamlets is multi ethnic, socio-economically deprived and one of the five Olympic boroughs for the Olympic Games in London 2012.

PURPOSE: To evaluate pedometer determined physical activity and body composition in 11-12 yr olds in Tower Hamlets.

METHODS: All secondary schools in the borough were invited to participate. A sealed pedometer was worn for 7 days. Internationally recognised mean daily step count cut-offs (boys = 15000, girls = 12000) were used to define activity level. BMI, BIA-determined %bf and WC were all measured. Children were classified as being of normal weight, overweight or obese according to international cut-off points. A questionnaire was also administered to establish socioeconomic status and ethnicity.

RESULTS: Boys took significantly more steps than girls ($p < 0.001$) (Table1). Activity was greater during the week compared to the weekend with a mean step count of 11,297 and 10,080, respectively. There was no significant difference by ethnicity or socio-economic status ($p > 0.05$).

Table 1 Mean daily step counts by gender and ethnicity

		N	Mean	SD	95% CI	
Boys	White	59	11325	35756	10394	12257
	S Asian	312	11551	3460	11166	11937
	Other	81	11876	3939	11005	12747
	All	**452**	**11580**	**3560**	**11251**	**11909**
Girls	White	64	9685	3320	8855	10514
	S Asian	141	10352	3208	9817	10886
	Other	24	9369	3122	8050	10687
	All	**229**	**10062**	**3239**	**9640**	**10484**
TOTAL		**681**	**11070**	**3527**	**10804**	**11335**

The interpretation of levels of overweight and obesity varied according to method of measurement. This ranged from 33.5%, 53.2% and 61.5% for BMI, % body fat and waist circumference, respectively (Table2). BMI cut-offs under-estimate overweight/obesity in a South Asian population.

Table 2 Percentage body composition according to 3 different measures

	BMI	WC	% BF
Normal	66.0	46.8	38.5
Overweight	20.5	23.8	16.5
Obese	13.5	29.4	45.0

There was no significant interaction between activity and body composition in this cohort.

CONCLUSION: The method of measurement needs to be considered when interpreting data reporting overweight and obesity with different ethnic groups and ages. Over 50% were overweight or obese. Only 16.6 % of boys and 27.9 % of girls achieved the minimum recommended daily step counts. Interventions to increase levels of physical activity need to be instigated in this age group.

Supported by an Icebreaker grant